Identifying the Importance of Performance Attributes for Innovations in Port Call Management

A BWM approach in multiple port cases

Master Thesis

Martijn Schoneveld

Delft University of Technology

TU Delft

Identifying the Importance of Performance Attributes for Innovations in Port Call Management

A BWM approach in multiple port cases

by

Martijn Schoneveld

to obtain the degree of Master of Science Transport, Infrastructure & Logistics
at the Delft University of Technology,
to be defended publicly on November 4th, 2022.

Student number: 4566114
Project duration: March 1, 2022 – November 1, 2022

Thesis committee:

Prof. dr. ir. L.A. (Loránt) Tavasszy,	TU Delft, chair
Dr. W.W.A. (Wouter) Beelaerts van Blokland,	TU Delft, first supervisor
Dr. R.M. (Rob) Stikkelman,	TU Delft, second supervisor
Dr. E.B.H.J. (Edwin) van Hassel,	University of Antwerp
Drs. ing. P.C.N. (Patrick) Everts,	KOTUG International

TU Delft KOTUG

Preface

This thesis is written as final step towards obtaining a degree in Master of Science Transport, Infrastructure, and Logistics at the TU Delft. This thesis is conducted in collaboration with KOTUG International at the Optiport department.

I would like to share my gratitude to Patrick and Lori for giving me this interesting research topic. After an interesting first discussion about the research topic, I started my internship back in March 2022 at KOTUG International. I would like to thank Patrick, Myron, and their colleagues for the warm welcome and the opportunity to be part of the KOTUG family. It was a great first experience as an 'office job' with the most beautiful office view in Rotterdam. And nice lunches.

Writing a master thesis always has some hiccups during the voyage. Finding the right committee members was quite difficult. In the end, it worked out well and I was lucky to have 5 enthusiastic and critical committee members. Whom have provided useful feedback to make my research better. Thank you Lori, Wouter, Rob, Edwin, and Patrick for the supervision.

On a more personal note I would like thank Marijn for our good discussions about our researches and developments in the maritime industry during weekly coffee breaks. Hope to keep nerding about maritime and logistics in the future. I would also like to thank fellow student mates for co-reading my thesis. Last but not least, I would like to thank my father for the opportunity to study and for giving great support and trust to complete my studies. A special gratitude to my mother, unfortunately in heaven, for her great upbringing and good educational support. This master thesis is dedicated to you. Furthermore, a thank you to the rest of my family and friends for their support.

As one chapter ends in life the next chapter starts. After 6 years of studying, I can call myself an 'Engineer'. As my dad would say: "Now it's time to start paying taxes and contribute to society son". As much as I enjoyed my student life, I am excited to start my working career.

Martijn Schoneveld
Delft, October 2022

Summary

The maritime shipping industry is struggling with several major challenges, supply chain congestion and a reduction of greenhouse gasses being two of them. Due to supply chain disruptions and increasing maritime trade, the performance of ports is under pressure. Many ports are challenged with peak congestion, leading to inefficient port operations. Long waiting times for vessels are harmful to the port's performance and lead to an increase in emissions. Ports around the world are looking for ways to improve their performance. Port call optimisation is a promising concept for improving port performance. Port call optimisation can be defined as a broad concept that aims to align stakeholders' activities during a port call process. Improving these processes can be done through different innovations. Different ports are looking for innovations that suit their port. It is important to research the relevant performance attributes on which an innovation could be evaluated. This facilitates ports' decision-making. It is also relevant to research the preferences stakeholders have when evaluating innovations. This gives insights into whether there is heterogeneity in preferences for innovations. The goal of this thesis is to identify the relative importance of performance attributes for innovations in port call management. This will lead to a better understanding of the different interests in ports and eventually improve alternative designs for various ports. The literature review shows a knowledge gap in identifying and understanding the different interests for improving the port call process. This thesis will thus answer the following research question: *"How do stakeholders in different ports value performance attributes for the evaluation of innovations in port call management?"*

Port call management describes the way a port call process is organised. The involved stakeholders in this thesis are: port authorities (PA), linesmen, a terminal, pilots, tugs, and one major shipping company. An innovation can be any kind of measure to improve the port call. A few examples are: data-sharing tools, asset optimisation tools, or autonomous nautical agents. Performance attributes are criteria on which innovations can be evaluated.

This thesis uses three methods to answer the research question: literature research, semi-structured interviews, and the Best-Worst Method (BWM). These methods have been applied in 6 port cases: the port of Sydney, the port of Hamburg, port Ras Al-Khaimah, port of Port Arthur, port Antwerp-Bruges, and port Tanger-Med. The result is a list of 17 relevant performance attributes. These are categorised into commercial effects, operational effects, and safety effects. The weights were gathered with the BWM and analysed on the macro- and micro-level. The performance of an innovation in terms of the amount of incidents and near misses, robustness, and added value are weighted relatively important. The performance on user-friendliness and flexibility is scored as least important. Innovations like autonomous nautical services will probably not be preferred. The results furthermore show that stakeholders weight performance attributes generally differently.

To conclude, the preferred innovation for improving port call management will differ per port case. Earlier studies on port call optimisation have concluded that port calls are managed differently and should be studied independently. This research has found similar results in the preferences for performance attributes. Besides the heterogeneity in preferences, there is also some homogeneity. The preferences within and between the ports Antwerp-Bruges and port of Port Arthur are found to be homogeneous. Within the port of Ras Al-Khaimah, homogeneity in preferences is also found. The heterogeneity and homogeneity in preferences are speculated to be influenced by the port context. The preferences of stakeholders could be influenced by factors like management structure, role of the PA, and nautical restrictions. This research is first in identifying performance attributes for port call innovations. The weights also provide insights into stakeholder's preferences for innovations in port call management. Further research is advised to build upon the knowledge of understanding preferences for port call optimisation in other port cases. This can increase the validity of the findings of this thesis. Research on how certain innovations perform could also be a next step in research. Such research can be done through simulation or agent-based modelling. This will give stakeholders more insights into the effects of certain innovations. For now, a general understanding of the preferences for innovations in port call management for certain port cases has been identified.

The following key takeaways from this thesis can be noted:

- 17 decision attributes have been identified as relevant for decision-making in the port call process. The attributes can be categorised into commercial, operational, and safety effects.
- Generally, safety effects have been valued as most important performance attributes for evaluating innovations in port call management. The most important attributes are *incidents*, *near misses*, *robustness*, and *added value*. The least important attributes are *user-friendliness* and *flexibility*.
- The stakeholders have weighted the attributes quite differently. This confirms that the port call is managed differently and that various preferences play a role in optimising the port call process. Understanding these preferences can lead to better decision-making and design of innovations.
- Some of these stakeholders' preferences can be understood by taking a closer look at the ports' problems and environment. In the studied port cases, ports with complex nautical restrictions prefer innovations that are safe. A studied port with centralised management is more commercially driven and more consensus is found on the most important performance attributes. Furthermore, management structure and the role of the PA can influence the preferences of stakeholders.

Contents

List of Figures

List of Tables

Nomenclature

Abbreviations

Abbreviation	Definition
ATA	Actual Time of Arrival
BWM	Best Worst Method
ETA	Estimated Time of Arrival
GHG	Green House Gasses
IMO	International Maritime Organisation
JIT	Just-in-Time
KPI	Key Performance Indicator
MCDM	Multi-Criteria Decision-Making
PA	Port Authority
PoR	Port of Rotterdam
PortCDM	Port Collaborative Decision-making
PTA	Planned Time of Arrival
VTS	Vessel Traffic Service
RTA	Recommended Time of Arrival

Definitions

Keyword	Definition
Demurrage costs	is the price you pay for storing a container at a terminal longer than planned. It is a indication of monetizing waiting times.
Innovation	A innovation in this thesis could be any kind of measure or intervention to improve the port call process.
Performance attributes	Attributes can also be explained as a criteria. This is a quality or characteristic part of something.
Port call	The processes steps of berthing an arriving or departing vessel.
Port call management	Port call management describes the way the port call processes are organised.
Port call optimization	Utilizing the resources and aligning the activities of the nautical service providers as efficiently as possible.
Port factors	Factors that may describe a port's environment.
System level	A level of detail that studies a system (like a whole port) on a higher hierarchical level.

1 Introduction

This chapter is the introduction and holds the following. The challenges and problems handled are described. The relevance to the literature will be described. Furthermore, the research scope, goal, and questions are presented.

1.1 Maritime challenges

The Maritime shipping industry is struggling with two major challenges: supply chain congestion and the reduction of greenhouse gasses. First of all, supply chain congestion has become an increasing challenge due to disruptions by the global pandemic. The maritime shipping industry plays an important role in the supply chain as about 80% of international trade is traded by maritime (Sirimanne et al., 2019). A report by UNCTAD, 2021, shows that the port calls are slightly dropping but the vessel sizes are increasing. Before 2019 the port calls were gradually increasing, but after 2019 there has been a slight drop which could be explained by the global pandemic. If the trend from before 2019 continues the volumes will increase in the future. Due to the disruptions in the supply chain, some of the ports are operating at maximum capacity. Because of this, congestion levels are rising causing longer waiting times outside the port and slower turn-around times for vessels UNCTAD, 2021. These congestion problems are very visible in some of the most important ports like Los Angeles, Rotterdam, Hamburg, Felixstowe, etc. These ports have a poor 'Container port performance index', as reported by World Bank, 2022. The high congestion level in ports leads to longer waiting times for vessels. A study from UNCTAD concluded that a given vessel spends a median of 23.5 hours during a Port Call (WARTSILA, 2019). Another study, from the International Maritime Organisation (IMO, 2020b), estimated that vessels spend up to 9% of their time waiting at anchorage. Waiting times harm the port performance but also the vessels. Vessels are high-value assets and are built to sail, not to wait at anchorage. Waiting time for vessels are very expensive for the vessel owner and cargo owners, these costs are referred to as demurrage costs. Vopak has estimated the costs of demurrage in the global supply chain to be 180 billion USD (Brand, 2022). Thus long turn-around times due to waiting time at ports are not preferred.

The second major challenge is the reduction of greenhouse gasses. The International Maritime Organisation (IMO) has set goals to reduce the carbon emissions of global shipping by 50% by 2050 compared to 2008 IMO, 2018. A reduction is essential as the shipping industry is responsible for 3% of the total CO_2 emissions. Besides its effect on CO_2 emissions, the shipping industry has a local effect on the air quality around ports when vessels are waiting at anchorage. The idle engines generate nitrogen oxides (NO_x) and sulphur oxides (SO_x)(Winebrake et al., 2007). Thus, the longer the vessels wait at anchorage, the more fuel they burn and the more greenhouse gas (GHG) emissions they emit.

Longer anchorage times cause higher emissions and further congestion in ports. These challenges ask for improvements in shipping and port operations. Broersma, 2021, mentions possible areas of improvement that can be divided into voyage efficiencies and port efficiencies. Voyage efficiencies involve vessel changes and speed optimisation. Speed optimisation is where the vessel's speed is calculated to save fuel consumption but still arrive within a certain time window. The port efficiencies involve solutions within a port to handle increased volumes. Research on voyage efficiencies in terms of speed optimisation is fairly common. An example of such an improvement is also called green steaming, which is to lower the vessel's speed to reduce fuel and GHG emissions Watson et al., 2015. A requirement to allow for green

steaming is to have good information about berth availability and nautical capacities to avoid anchorage time at ports. Research on port efficiencies is mostly common regarding terminal optimisations and berth allocation problems (Wijma et al., 2018; UNCTAD, 2021). This thesis will add to research on port efficiencies focusing on processes within the port, as this is an understudied topic. Port efficiencies are determining port performance.

1.1.1. Port performance and efficiency

Ports are important nodes for the supply chain. Some ports perform in a tough competitive market (Trujillo and Tovar, 2007). When vessel agencies plan a vessel's voyage they typically find costs and transport time important factors for selecting ports (Rezaei et al., 2019). For ports to stay competitive, it is important to have efficient operations in a port (Tongzon, 2009). Short turn-around times with short anchorage times are important criteria for a port because short turn-around times can increase the throughput of a port. With the increasing congestion peaks and IMO GHG strategy, ports are looking for ways to reduce their turn-around times to stay competitive (UNCTAD, 2021). Congestion of a vessel in or out of the port usually leads to disruptions and deviations causing further delays in berthing schedules and other services (Notteboom, 2006). Disruptions and deviations lead to higher congestion levels. Higher congestion levels in turn reduce the port performance. A few causes of delays in ports can be limitations in spatial and operating efficiency, limitations in maritime and landside access, inadequate oversight, and poor coordination between the public agencies involved, resulting in a lack of predictability and reliability (World Bank, 2022). A few of the poor-performing ports were mentioned in the previous section.

The reason why ports perform inefficiently can be many and is often rather complex. On top, it can be case-specific varying each year. The two most frequent delays in the Port of Rotterdam (PoR) are caused by tugs or pilots not being available or due to delays by previous berthed vessels (Nikghadam et al., 2021). UNCTAD suggests three policy measures that could improve the port performance: Port call optimisation, facilitation, and port operations (WARTSILA, 2019). Port operations refer mostly to terminal operations and is much researched and often fairly optimised already. Facilitation concerns the physical aspect of building extra infrastructure to accommodate more vessels. According to WARTSILA, 2019, port call optimisation is the most promising as it can bring the most gains. The benefits extend to the local environment in terms of GHGs and time efficiency. Port call optimisation can be interpreted broadly but is a concept that could contribute to improving the mentioned challenges in maritime shipping.

Port Call Optimisation

There are several definitions and understandings of port call optimisation. First of all, the IMO refers to the concept of just-in-time (JIT) arrivals (IMO, 2020b). JIT arrivals allow for a vessel to maintain an optimal sailing speed to arrive at the port at a time when the availability of 1. berth, 2. fairway, 3. nautical services is ensured (IMO, 2020b). For JIT arrivals, information should be shared well in advance so that ships can adjust their speed in such a manner that it minimises waiting times. JIT arrivals can reduce up to 14% in emissions (IMO and Roumelioti, 2022). Furthermore, Lind et al., 2018 explain port call optimisation as the process of making the port call process as efficient as possible according to the needs of involved stakeholders. In this thesis, port call optimisation is referred to as the internal optimisation of port call processes in a port. In other words, ensuring that all processes happen on time without congestion. Lind, Ward, Bergmann, et al., 2020, have proposed to start with standardisation of messaging during a port call. The International Taskforce Port Call Optimisation have reacted to this by releasing a guide to standardise nautical messaging during a port call (**portcalloptimisation_2018**). This should improve the information sharing between port operators in light of JIT arrivals. Several studies, (Wijma et al., 2018, Nikghadam et al., 2021), have shown the benefits of information sharing in terms of time savings and emission reduction.

Whether it's standardising nautical data or improving information sharing, they both can be considered as measures to optimise a port call process. In this thesis the focus is on the internal port call processes, also referred to as port planning. The internal port call processes can be described as the activities performed prior to, during, and after the visit of a sea vessel in a port (Lind et al., 2015). In other words, all processes are needed to berth a sea vessel. Figure 1.1, represents the activities that need to

be aligned. These processes are complex, due to the many stakeholders needed to complete a port call. The stakeholders involved are terminals, port authorities (PA), pilots, tugs, and linesmen (i.e., moorers). These stakeholders can be referred to as the nautical chain. All the activities of these stakeholders need to be aligned to perform a port call successfully and eventually allow for port call optimisation. The activities are dependent on each other, meaning that all stakeholders have to complete the job sequentially or simultaneously. Aligning the activities accordingly can be a difficult task. Specifically when many different firms are involved. Besides the port call being complex, it usually operates in a self-organising business ecosystem, meaning that many different stakeholders have to work together but all work independently (Lind et al., 2018). In many ports the stakeholders compete against each other thus collaboration is difficult to achieve. These competitive attitudes are deeply rooted in the port's organisational structure. Some ports experience less competition, making collaboration easier. It may be that these kinds of ports are easier to optimise. However, is there a similar need to optimise?

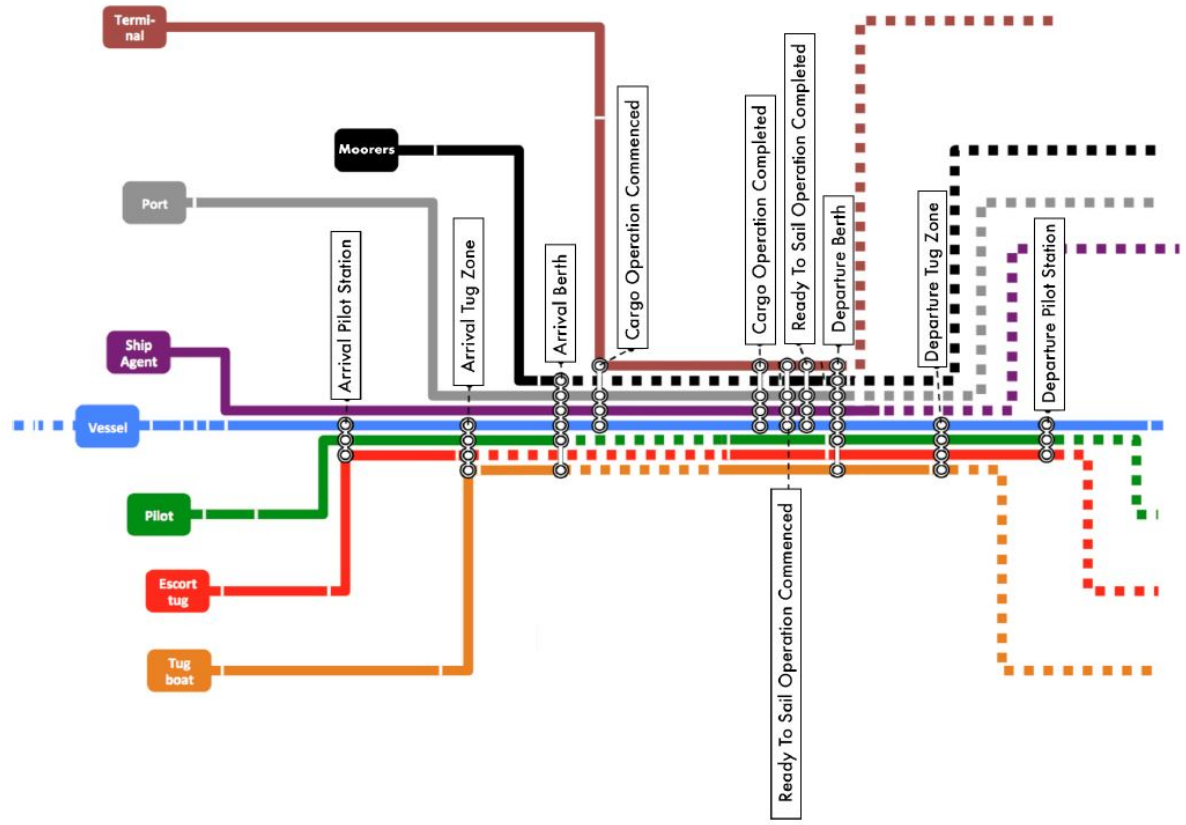


Figure 1.1: Port Call Process represented in Metro map Lind et al., 2016

Port call optimisation can thus be allowing for JIT arrivals but also optimising processes within a port such that the resources are available for JIT arrivals. Port call optimisation can contribute to the two major maritime challenges if correctly implemented. However, optimising the port call process can be rather complex. The implementation is dependent on the interests of the involved stakeholders and possibly case-specific. Each port has its unique characteristics affecting the preferences to implement a port call optimisation measure. Thus, optimising port calls must be tailored to the specific port. Port call optimisation is a promising step to reduce turn-around times within ports and allow for JIT arrivals to reduce GHG. Optimisation can be done through different measures or innovations. Some innovations are explored in section 2.2.4.

1.2 Problem Statement

As has been described above, the maritime shipping industry is facing two major challenges regarding increasing congestion and GHG emissions. These challenges have put extra pressure on the port's performance. The competitive nature of the maritime shipping industry forces ports to become more efficient in terms of turn-around times. Port call optimisation is a concept that many ports and shipping companies see the benefits of, but it remains complex due to the stakeholders involved. The solution to port call optimisation can also be case-specific depending on the port's environment.

Several researches have addressed problems in the port call processes. During peak congestion times the capacity of the nautical services is usually not enough to handle the vessels, leading to more delays Molkenboer, 2020. If congestion levels continue to rise then this will more frequently become a problem. Often lack of predictability or delayed port operations is a problem leading to further delays Wijma et al., 2018. The underlying cause of problems in the port call process is a lack of information sharing and collaboration in port planning (Broersma, 2021; Nikghadam et al., 2021). The solution for enabling information sharing or collaboration is not as straightforward due to the complexity of the port call process. The industry is looking for suitable innovations to reach port call optimisation. However, the preferences of stakeholders are unknown. These preferences probably differ per port. Research into these preferences and why the preferences differ is currently lacking. Conducting research into the preferences of stakeholders can lead to better alternative design and eventually ease decision-making for port call optimisation Keeny, 1996. Understanding the preferences of stakeholders can lead to the design of suitable innovations for port call management.

1.3 Knowledge Gap

The topic of port call optimisation is fairly scarce. Literature exists in quantitative and qualitative forms. Qualitative studies have researched reasons for delays in port call management with data analysis (Nikghadam et al., 2021; Vieira et al., 2015; Michaelides et al., 2019). Simulation studies have researched the effects of port call optimisation on time and emissions (Wijma et al., 2018; Lokin, 2022). Qualitative research focuses on definitions and concepts towards port call optimisation (Lind et al., 2018). Also how information sharing could benefit port call optimisation (Molkenboer, 2020). Imset, 2021, has identified drivers and barriers for port call digitisation. The benefits and necessities have been acknowledged by these sources. Implementing measures for port call optimisation would be the next step. Ports are looking for suitable innovations according to their needs. However, the need for innovations has never been researched before. There is a knowledge gap on what preferences stakeholders have for evaluating innovations in port call management.

This thesis contributes by identifying and understanding the relative importance of factors for the evaluation of innovations for port call management. The gap of this thesis is partly to identify what the relevant performance attributes are for evaluating innovations for port call management. The other part is to identify the relative importance of these performance attributes. Innovations can be any kind of measures to reach port call optimisation. For example: data-sharing tools, asset optimisation tools, or autonomous nautical agents. The exact innovation is not important at this stage because the preferences of stakeholders in ports have not yet been explored. According to Keeney, 1996, exploring the preferences first can lead to better design of alternatives (i.e., innovations). It has not yet been researched if there are differences between preferences and if these differences can be explained by the context of the port. The context of a port explains the port's environment. To find out whether a certain structured port scores criteria differently than another, a multi-case study is performed. As far as the author is aware, comparing various port call processes in ports with different port contexts has also never been done before. By closing these research gaps, there will be a better understanding of what the preferences are in various port contexts. This can lead to better design of innovations and ease decision-making.

1.4 Research Scope

The scope of this thesis lays particularly on identifying the importance of performance attributes for innovations in port call management. The importance of the port call stakeholders in the port planning stage of the port call will be identified. The port call processes in the port planning stage are all the steps prior to and after the berth of a vessel in a port. In other words, manoeuvring a vessel into and out of a port. The processes are described in figure 1.1. The port call process starts when the captain first makes contact with the port until the vessel leaves the port area, further described in chapter 4. Services like cargo operations and bunkering do not have relevant information for the nautical services and can be described as static and reliable (Wijma et al., 2018). Thus there are fewer efficiency gains in these steps. For this reason, the unloading operations and bunkering services during berth are considered fixed processes. Also, the optimisation of the vessel's voyage will not be taken into account because this requires coordination between ports. This can be seen as the next step of port call optimisation, which is beyond the scope of this thesis. The departure processes of a vessel are similar to the arrival processes and will be taken into account by the nautical service providers. When referring to a vessel this thesis refers to a deep-sea cargo vessel. Furthermore, no limitations on the type of cargo are accounted for. This is a factor that could influence the port call processes. The cargo can be container, dry-bulk, or liquid bulk. There are also different understandings of port call optimisation. There are different ways to optimise the port call process. An innovation for port call management could be anything from a tool to a policy. In this thesis, an alternative or measure to improve the port call process will be referred to as an innovation for port call management. This research will not evaluate the performance of innovations. This thesis focuses on how stakeholders value performance attributes for evaluating innovations in port call management. The ports studied are located in Ras Al-Khaimah, Antwerp, Hamburg, Sydney, Port Arthur, and Tanger-Med. Ports are selected globally, each with a different organisational structure and unique rules. The key stakeholders in the nautical chain are: the port authorities, pilots, tugboat companies, linesmen, and terminals. These will be referred to as port call stakeholders in this thesis. The shipping company can also play a key role during the port call. This is however not bonded to a port.

1.5 Research Goal

As described earlier, one of the key challenges in ports is to handle increasing congestion caused by delays of vessels and inefficiencies in the port call processes. The port call process is often a bottleneck in the port and disruptions in these processes cause more delays, as there is a strong dependency between departing and arriving vessels. The delays of a current vessel at berth directly impacts the next vessel for berth leading to waiting time. This hurts the turn-around time in ports and affects the port performance and efficiency. It has been researched that these delays can be mitigated with port call optimisation. Optimisation of the port call process can be done through various measures and innovations. Such innovations can be a platform or other software tools to enable sharing information. The common situational awareness that follows from this can benefit the nautical service providers in planning their assets. A tool or measure promoting collaboration and information sharing can be considered as port call optimisation. Innovations like intelligent planning tools or remote pilotage could be considered. Before the port call stakeholders adopt innovations for port call optimisation, it is important to identify the performance attributes and the weights stakeholders give. Seen that the port call is rather complex, the preferences could differ per port. Possibly a trend could be identified between certain ports and the preferences of stakeholders. It thus may be possible that the preferences could be explained by the context (environment) of a port, like organisational structure, type of contracts, responsibilities, and type of cargo (Poulsen and Sampson, 2020; Van der Lugt et al., 2015; Munim et al., 2020). The selection of an innovation for port call management, in a given port, is a decision-making process where the most preferred alternative according to multiple stakeholders is scored highest. Insights into the relevant performance attributes can help with the design of suitable innovations. The goal of this thesis is to identify how stakeholders weigh performance attributes for evaluating innovations in port call management. Interesting will be whether differences or similarities in stakeholders' weights show a certain trend that can be explained by the port environment. By using the Bayesian Best Worst Method (BWM) of Mohammadi and Rezaei, 2020, weights of attributes can represent the relative importance of group decision-makers. Relative differences in weights can be considered differences in preferences of certain attributes. This goal leads to the following research questions.

1.6 Research Questions

The main goal of this research is to identify the importance of performance attributes for innovations in port call management. The importance of performance attributes can be illustrated by a scale or ranking and is determined by the involved stakeholders. The importance of criteria is identified in different ports to understand how the weights are scored in different environments. With this goal in mind, the following main research question is proposed:

"How do stakeholders in different ports value performance attributes for evaluating innovations in port call management?"

The first goal is to find what performance attributes are relevant for decision-making in port call management. Criteria are explored during literature research. As this has never been done before, finding relevant criteria through literature research is not sufficient. For this reason, semi-structured interviews are performed to collect the objectives of relevant stakeholders. The criteria from literature will be combined with the criteria derived from the identified stakeholders' objectives to complete the performance attribute list. The following sub-question will be answered:

SQ1: What are relevant performance attributes for evaluating innovations in port call management?

The next step is to determine how the proposed performance attributes are weighted by the port call stakeholders. The BWM can be used to find the relative importance of attributes. This method is used to analyse how stakeholders value the proposed performance attributes. This analysis will also see if there is heterogeneity in the stakeholder's valuation. The following question deals with this:

SQ2: How are the proposed performance attributes weighted by the stakeholders?

After the attributes and preferences have been gathered, it will be analysed whether there is a structural difference between the way stakeholders score performance attributes for innovations in port call management. The stakeholder originates from different ports. The studied ports also differ from each other in terms of their environment. It could be that a port with a certain environment scores differently than another port. The following question refers to this:

SQ3: How can heterogeneity and homogeneity in weights be explained by the port cases?

1.7 Report Outline

Table 1.1, illustrates the thesis outline with corresponding methods and where the research questions can be found. Chapter 1 is the introduction of the thesis where the context of the research and problem statement is sketched. It explains why this research is conducted. Chapter 2 is the literature review; the background of this thesis can be found in this chapter. Existing literature on port call optimisation is presented and the gaps are identified. Chapter 3, the methodology, explains how the research is conducted. In chapter 4 the port call is described. The involved stakeholders and cases are described here. The descriptions were obtained from semi-structured interviews. The conclusion of this chapter gives an overview of the various ports' contexts. In chapter 5, the identified performance attributes for innovation in port call management are presented. This chapter answers the first sub-question. Chapter 6 presents the weights stakeholders gave to the identified performance attributes. This chapter aims to answer the second and third sub-question. The last chapter, chapter 7, is the conclusion and discussion where the answer to the main research question can be found.

Table 1.1: Thesis Outline

Chapter	**Activity**	**Research Question**	**Method**
Chapter 1	**Introduction**	-	-
Chapter 2	**Literature Review**	-	Literature research
Chapter 3	**Methodology**	-	-
Chapter 4	**System Description**	-	Semi-structured Interviews
Chapter 5	**Attributes for evaluating innovations**	SQ1	Literature Research & Semi-structured Interviews
Chapter 6	**Relative importance of criteria**	SQ2 & SQ3	Bayesian BWM
Chapter 7	**Conclusion & Discussion**	RQ	-

SQ: Sub-Question & RQ: Main Research Question

2

Literature Review

This chapter will review existing literature about port call optimisation. From the 24 articles found in Scopus and some forward and backward snowballing, 11 studies have been reviewed. Besides these studies, some grey literature by the IMO and researches complete the total literature reviewed. An overview of the papers can be found in table 2.2. The conclusion of the literature review will also present the research gap. This supports the formulated research goal.

2.1 Port call optimisation

Port call optimisation is not a huge research topic in literature. Only 24 related articles can be found in the search engine Scopus. Lind et al., 2018, describes port call optimisation as the process of making the port call as efficient as possible according to the needs of involved stakeholders. This definition includes external and internal processes, namely port call synchronisation and port call coordination. Port call synchronisation concerns coordinating operations port-to-port from a ship's approach. Port call coordination is more about aligning each stakeholder's action with other stakeholders with a common objective of interest (Lind et al., 2018). The goal of this report focuses more on the latter. Port synchronisation would require agreements between ports which is an interesting research topic, but also a very complex one. In this report when talking about port call optimisation it refers to internal processes within a port, as explained in the system description in chapter 4. Furthermore, WARTSILA, 2019 describes port call optimisation as ships arriving right on time, by effectively communicating with the parties in the port. In such a way that when the vessel arrives, it can directly be berthed without having to wait. Saving waiting time, reducing the turn-around time, and reducing total emissions. All in all, improving the port performance. In this thesis, port call optimisation will be understood as aligning all internal processes of the port call. Similar to the definition of port call coordination from Lind et al., 2018. The literature reviewed on port call optimisation can be divided into quantitative findings and qualitative findings.

Quantitative findings

Veenstra and Harmelink, 2021, have collected data about arrival times in ports. They concluded that shipping liners offer poor and optimistic arrival estimates which are usually inaccurate. Vessel agencies often communicate an exceedingly optimistic arrival time to the port to ensure a berth allocation. As many ports serve vessels in a first come first serve manner, the vessel agency hopes to guarantee a slot by giving an optimistic ETA. This results in unnecessary waiting time for vessels and poor port performance. The inaccuracies in arrival times are mentioned by several interviewees and studies (Lind et al., 2019; Nikghadam et al., 2021). They state that inefficiencies usually happen due to a lack of information sharing. For example changes in ETAs are not being communicated.

A second quantitative study in Cyprus and other Mediterranean ports studied the effect of port-to-port communication in short sea shipping. Calculated KPIs like arrival punctuality, berth waiting, and berth utilization were identified. research shows these factors influence various waiting times. The analysis revealed a considerable variation in agent performance regarding the KPIs (Michaelides et al., 2019). Similar findings of the more quantitative studies of Veenstra and Harmelink, 2021. Measures are suggested using port-2-port communication of the Port Collaborative Decision-making (PortCDM) concept Lind et al., 2018. Furthermore, sharing data and transparency among involved stakeholders in

a port call is proposed.

Besides improvements in time efficiency, port call optimisation can also reduce emissions of vessels during a port call (Lokin, 2022). This thesis modeled a control structure based on the information sharing concept of PortCDM by Lind et al., 2018 to optimally control the speed of incoming vessels and shift the berth time windows at terminals based on accurate information. The main objective of the optimisation is to minimise the maximum deviation between the ship being ready and the actual start time of operation. The results showed a reduction in total emissions but a slight increase in time spent in port. This is logical as the approach speed can be reduced for incoming vessels. Furthermore, Lokin, 2022, reports the sub-objectives of each stakeholder in table 2.1. This thesis is unique in reporting stakeholder's objectives which can be used as a reference point when identifying performance attributes.

Table 2.1: optimisation objectives (Lokin, 2022)

Stakeholder	**Objective**
Captain	Vessel arrival and departure without waiting time (depends on cargo type)
Nautical services	Optimal asset use and allocation
Harbour Master	Operations optimised for safety and throughput
Terminal operator	Berth utilization

Virtual Arrival Schemes are used to match the vessel's arrival time according to the resource readiness of the port. The thesis of Lokin, 2022, uses virtual arrival schemes as controller for his model. The idea is that vessel's speed can be optimised during the voyage to meet revised arrival times at ports. With the use of this specific model the total emissions were reduced significantly. However, the time increased slightly. This is an important trade-off vessel agencies have to make. Such research is often referred to as just-in-time (JIT) arrival by the IMO, 2020a. According to Broersma, 2021, this policy did not advance in the industry because there are sharp financial incentives not to delay a vessel. On top of that a problematic relationship with fear of losing port services in a 'first come, first serve' system. Another vessel may be able to pick your port slot, leading to more delays in ports. Thus probably the order the port serves vessels can be an influential factor in determining port call management.

Port call optimisation is likewise studied in the concept of JIT arrival to optimise the speed during a voyage to arrive at the port when the availability of berth and nautical service providers are ensured IMO and Roumelioti, 2022. This study is performed by MarineTraffic and the results show that a fuel saving of 14% can be reached if the voyage is optimised from pilot boarding place to pilot boarding place. Optimisation for vessel voyages 24 hours and 12 hours before the arrival at the pilot boarding place also shows substantial fuel savings. The optimisation of vessel voyages falls out of the scope of this thesis as this thesis is looking into port call optimisation for nautical services. This study however also emphasises collaboration in terms of data sharing between shipping lines, ports, and terminals to realise the benefits of JIT arrival.

The main cause of inefficiencies can be improved if the operations during a port call would be more predictable and communication between parties would be more transparent (Wijma et al., 2018). Simulation models have described the key processes of the port call and simulated possible interventions for the PoR (Davydenko and Fransen, 2019; Fransen and Davydenko, 2021). These interventions are more collaboration by sharing the vessel's PTA and ETA with everyone. Data analysis from deep-sea vessels in the PoR have shown that waiting time accounts for the largest part of turnaround time in a port. Furthermore, the unavailability of nautical service providers will profoundly increase the vessel waiting time at anchorage (Gan, 2019).

Qualitative findings
The first qualitative research has identified barriers and drivers for port call digitisation transformations (Imset, 2021). Drivers and barriers were explored in two different ports in Northwest Europe. Most identified drivers and barriers are related to ecosystem level, meaning collaborating and participating is important when developing digital platforms. The most common driver was to use digitalization such that it generates value for themselves and the customer. Another common mentioned driver is an increase in efficiency, and a reduction in costs, time, and resources. The most common barrier was that digitalization poses a threat to their business by reduction of activities. Thus digitalisation is seen as having great potential but also as a great threat by the stakeholders. The need for digitisation is also confirmed by Ceder et al., 2018, who found that collaboration through information sharing and digitisation could benefit the port call. The identified drivers and barriers are collected through semi-structured interviews. This gives an idea of what the attitude is toward digital platforms. This thesis will explore alternatives beyond digital solutions.

Another re-occurring topic concerning port call optimisation is collaboration. Lind et al., 2015 defines it as aligning all the stakeholders involved in the nautical services. He suggests information-sharing protocols for how and with whom to share what information during a port call. Similarly, the International Task Forces of Port Call optimisation are settling on standards for universal use of definitions. These standardised definitions are important so that there is no miscommunication and it allows for collaboration. Molkenboer, 2020, has researched information-sharing for the PoR of the nautical services. The conclusion was that terminals are often not up to speed with the nautical situation and the other way around. Different communication tools are used to make communication threads instead of a good network. Communication about operational updates goes through phone calls or VHF radio for internal communication and between organisations. This leads to information being missed and operators taking incorrect decisions. It generally leads to reduced situational awareness. Nikghadam et al., 2021, builds on information sharing research by suggesting arrangements of information sharing.

Literature on Port call optimisation is mostly dominant with a quantitative approach. The quantitative researches are mainly data analysis on port call efficiencies and simulation studies for future analysis. Qualitative literature is less dominant in port call optimisation. The performed literature is mostly about standardising protocols for collaboration and exploring communication threads. Barriers and drivers for port call digitalisation have also been identified. It can be generally concluded that the benefits of port call optimisation have been identified. Still, the problems and solutions for port call optimisation are different in every port. Optimising the port call can be considered a motive to increase the performance of a port. Several studies have explored possible measures and impacts of port call optimisation, which seem promising. As little as it is in the literature, it is early stages for port call optimisation. A port call is a very complex process, with many different involved stakeholders with various interests. Port call optimisation can be reached through several measures. This research will further build upon the exploration of the preferences stakeholders have for evaluating innovations in port call optimisation. Port call optimisation is not seen as a goal or measure but as a motive to research.

2.2 Applications of Multi-Criteria Decision Making in ports

2.2.1. Multi-Criteria Decision Making Models

As far as the author is aware, a Multi-Criteria Decision Making (MCDM) model has not yet been applied in the field of port call management or exploration of innovations for port calls. The optimisation problem is often studied quantitatively through simulations and data analysis, as can be concluded from the sections above. Simulations are good ways to evaluate the effects and causes of particular policies or interventions. One step before simulating is exploring the needs and interests of the different stakeholders. The main difference between simulation studies and MCDM studies is that MCDM is not looking for an optimal representation of one environment. MCDM leads to insights into the preferences of stakeholders whom weight criteria for evaluation of alternatives (Macharis and Bernardini, 2015). An MCDM is a good analysis for making decisions in a multi-actor and multi-criteria setting (Rezaei, 2015). Browne and Ryan, 2011, also describes it as a method to rank alternatives that satisfy the criteria best based on the values of decision-makers. Criteria can also be referred to as attributes, explaining a quality or characteristic part of something. Innovations are explored over multiple goals instead of solutions reaching one goal. Given that this study focuses on the exploration of stakeholders' preferences for innovations in a multi-actor, with actor-specific objectives, a multi-criteria decision-making approach is most relevant for this research. An MCDM can indicate the preferences in different case studies. This MCDM will find the relative importance of attributes to represent the preferences of stakeholders.

With multiple stakeholders and multiple interests involved, an MCDM is a relevant method to explore potential innovations for port calls in various ports. Macharis and Bernardini, 2015, suggests a Multi-actor multi-criteria decision-making being useful for several transport decision problems. MCDM is often used for comparing different modes of transport (Macharis and Bernardini, 2015). As described in chapter 4, multiple stakeholders are involved in the port call process. When ranking the criteria of the MCDM, the results could give a good indication of the different interests for proposed performance attributes. The interests of stakeholders will probably be different from each other. It will be interesting to see how the preferences compare between various ports.

Furthermore, Browne and Ryan, 2011 states that cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) are popular evaluation methods for transportation projects. CBA is typically used for project evaluation of new infrastructures for public transport projects. It is a useful tool to evaluate the monetary effects of alternatives. According to a survey of transport politicians the CBA is used as a decision tool but it doesn't dictate the decision. CEA is more generally applied to broader policies but for transport usually for technology options of fuel alternatives. For this problem, an alternative comparison is preferred above monetary effects because the right solution is yet to be explored. It is early stages of exploring what alternative fits the problem of port call. Monetary effects could be relevant for a follow-up study.

2.2.2. Determining weights of performance attributes

In an MCDM several alternatives can be evaluated concerning proposed criteria, which are also weighted by decision-makers, to eventually select the best alternative (Rezaei, 2015). MCDM can be distinguished by the methods for determining the weights of the criteria. This thesis will focus on determining the weights. The most popular is Analytic Hierarchy Process (AHP) where the weighting is arranged in hierarchical order (Saaty, 1990). Another popular method is the Analytic Network Process (ANP), which is a continuation of AHP, but instead of hierarchical order, a network structure is used. The third method is Best-Worst Method (BWM), which uses pairwise comparisons to determine the weights of criteria. This study will use the BWM to identify the preferences of the stakeholders for innovations in port call management. The BWM is a suitable method to find the importance of certain performance attributes which are used to find a solution. BWM is furthermore chosen because it requires less data compared to the other methods and it leads to more consistent comparisons Rezaei, 2015. The use of two pair-wise comparisons mitigates the chance of bias from the decision-makers. Due to the uniqueness of this problem, very little data is available.

The BWM has been used in two earlier relevant port studies. The first research is the exploration of

criteria and preferences of decision-makers in the future shipping environment of the PI (Fahim et al., 2022). The second research is identifying port performance and the port choice by shippers, freight forwarders, and carriers (Rezaei et al., 2019). Furthermore, BWM has been used in many other sectors to explore decision criteria and the preferences of decision-makers. For example in designing an optimal configuration of a pick-up and delivery scheme for the airport cargo sector (Schutte, 2020). Thus it can be said, BWM is a suitable method to identify the importance of stakeholder interests in a decision-making context for innovations in port call management.

The BWM knows several variants of the method. The traditional BWM is very good to find the optimal weight of criteria for a single decision-maker. However, it cannot calculate aggregated weights of multiple decision-makers. When aggregating weights, the arithmetic or geometric mean is usually used. Mohammadi and Rezaei, 2020, has developed a Bayesian BWM to find the aggregated final weight of a group of decision-makers. The Bayesian BWM takes a probabilistic approach to model the optimal weights. This leads to similar performance compared to the traditional BWM and, provides much more information. Seen the multi-actor context of this topic, a Bayesian BWM is more suitable than the traditional BWM.

2.2.3. Performance attributes for port call management

Selection of an innovation for port call management, in a given port, is a decision-making process where the most preferred alternative according to multiple stakeholders is scored highest. The most preferred alternative is determined by the attributes and the weights the decision-makers give. This is the aspect this thesis will focus on. The decision-makers are the involved stakeholders of a port call. Typically there is a pilot, tug operator, linesmen, port authority, and terminal involved in a port call process. To make decisions based on multiple performance attributes it is important to know how stakeholders value attributes. As far as the author is aware, there are no studies that have captured attributes for innovations for port call optimisation. Research on port calls has given some insights into what objectives are important and what barriers and drivers stakeholders have, to digitise the port call. These can be rewritten to performance attributes. As mentioned in the previous section, the BWM has been used for related research topics in ports and aviation. Objectives for port call optimisation have not been found in literature.

The thesis of Lokin, 2022, is the only literature that reports on the different objectives in port call optimisation. He provides insights on the several optimisation objectives various stakeholders have during a port call process. From this list (table 2.1) it becomes evident that each stakeholder has different optimisation objectives. Minimising waiting time is a top priority of the captain however the nautical services want to optimise asset allocation. Similarly, the optimisation objectives of the harbour master and terminal operator also collide with each other. The stakeholders in the port call have different optimisation objectives. Furthermore, research on what the attributes are and how stakeholders value them is lacking in the literature.

2.3 Factors affecting the port call management

From the literature reviewed the studies often mentioned factors affecting port call management. These are factors usually describing the context of a port that influences how the port call is managed. The influences are factors that can characterise the port. Several studies have pointed out possible factors affecting the port call.

First of all, Van der Lugt et al., 2015 has concluded that a PA with more autonomy and a more business-like strategy widens its strategic objectives in terms of port alternatives. Secondly, Lind, Ward, Bergmann, et al., 2020 points out that decentralised ports like Antwerp become more complex to organise because of it's port in port structure. Thirdly, in a report of the IMO IMO, 2020a, the willingness to share data varies per port en depends on the power of the PA, and nautical services, whether they are privately or publicly governed. Fourthly, the port management model is said to be influential on what drivers and barriers stakeholders have for digital solutions in ports (Imset, 2021). It is similar to the PA strategy of Van der Lugt et al., 2015. The level of collaboration is beneficial to the willingness to share information (Ceder et al., 2018). They mention that commercial incentives often do not foster collaboration in a port. This has also been mentioned in the conducted interviews of this thesis. The order of serving vessels is mentioned to impact just-in-time arrivals by Lokin, 2022. He mentions that first-come, first-served is leading to faster sailing speeds and inaccurate sharing ETAs.

Lastly, Talley, 2009 has evidence that terminal ownership is an important factor influencing the port's turn-around time. In tanker shipping, vertical integration between cargo owners and terminals is common. In container shipping, vertical integration is also common, but here container lines own the terminals. Poulsen and Sampson, 2020 mentions, waiting time in a port is dependent on the cargo type. The frequency of ships is a factor vessel agencies consider when selecting ports (Rezaei et al., 2019). The port call differs depending on the type of cargo. Container calls are part of a larger schedule with multiple port visits. Cruise calls are planned 1 or 2 years ahead of time. Regular passenger traffic is often repetitive. Bulk is highly dependent on supply and demand, driven by market prices (Lind et al., 2021).

- PA Strategy (Van der Lugt et al., 2015)
- Centralised vs Decentralised (Lind, Ward, Bergmann, et al., 2020)
- Public vs private owned services in ports (IMO, 2020a)
- Port Management model (Service port, landlord ect) (Imset, 2021)
- Level of collaboration (Ceder et al., 2018)
- Order of serving vessels (Lokin, 2022)
- Vertical integration vessel agencies and terminals & Type of cargo (Talley, 2009; Poulsen and Sampson, 2020)

PortCDM has been tested in 9 different ports in both the Mediterranean and Nordic area (Lind et al., 2019). The conclusions from these validations are that PortCDM works best in ports where data protection is not a problem. In other words, stakeholders don't have a huge competitive culture. This is logical as PortCDM works best if all participants are willing to collaborate by data sharing. This is one of the barriers mentioned by Imset, 2021. Nikghadam et al., 2021, also mentions that collaboration is easier if their communication bond is stronger. If stakeholders do not have a strong communication link the chances that they are willing to share data and collaborate are lower.

Literature concerning port call optimisation or collaboration each has its own caveats. The studies above mention factors that make collaboration more difficult or could influence the ability to optimise. These factors could be used to explain heterogeneity or homogeneity in the stakeholder's preferences for the evaluation of innovations.

2.4 Literature gaps

From the literature reviewed on port call optimisation, a few findings can be made. The quantitative research has mainly pointed out where the inefficiencies are with data analysis and how to mitigate these (Nikghadam et al., 2021 & Vieira et al., 2015 & Michaelides et al., 2019). Simulation studies have also illustrated the positive impacts of measures of port call optimisation on waiting times and emissions (Wijma et al., 2018 & Lokin, 2022). More qualitative research explores drivers and barriers for port call digitisation Imset, 2021. Concepts for collaborative decision-making and information sharing in port call management has also been researched (Lind et al., 2018 & Molkenboer, 2020). These researches suggest concepts to promote collaboration within a port call (Lind et al., 2019). promoting collaboration through information sharing can create situational awareness and mitigate delays (Nikghadam et al., 2021). An overview of the literature studied is presented in table 2.2. Generally, it can be said that port call optimisation is a promising topic for port performance.

Drivers and barriers for port call digitisation solutions have been identified (Imset, 2021). The industry is scouting for suitable innovations to improve the port call processes. It has been proven that improving can benefit the port performance. Several innovations are being designed by the industry but the interests of the stakeholders in port call management have never been identified before. Often innovations are digital solutions but it can also be an asset or measure to improve the port call process in a port. It is still early days in the adoption of innovations for port call management. For a solution to be a good fit, it is important to first explore the attributes and weights the stakeholders give. These steps are part of a multi-criteria decision-making problem, where possible solutions for improving the port call process can be evaluated on a number of attributes. Before evaluating innovations for port call management it is important to identify the right attributes first. This thesis will contribute to the research gap by identifying performance attributes to evaluate innovations for port call management.

Using a BWM for evaluating innovations in port call management has never been done before. Identifying the criteria and their weights is none existent in literature. This method has been used in identifying selection criteria for ports and for designing pick-up and delivery strategies in airports. These applications prove the BWM to be a suitable method for determining the weights of performance attributes. In the studied literature on port call optimisation, one study has identified different optimisation objectives (Lokin, 2022). These are considered for evaluating port call innovations and can be used as starting point.

Due to the complex nature of the port call process, it is expected that there will be heterogeneity in the preferences of performance attributes. Lokin, 2022, briefly touches on this matter but other than that there is no supporting research on what the various objectives are during a port call. This research will fill in the gap of whether there is heterogeneity or homogeneity in stakeholders' preferences for evaluating innovations.

Furthermore, several studies have pointed out factors like: PA strategy and port management model to be influencial in how the port call is managed (Lind, Ward, and Bergmann, 2020; Imset, 2021). The way a port call is managed can be dependent on several factors. These factors are presented and explained in section 2.3. These factors could have some influence on what the preferences are for innovations. It might be possible that the differences in preferences can be explained by the context of the port. The relation between these factors and preferences has never been researched either. Understanding differences in preferences is also a gap in literature. This thesis will explore whether preferences of criteria can vary depending on the port's context.

Table 2.2: Literature review overview

Author	Research focus	Contribution
Lind et al., 2018	PortCDM	Proposes a collaborative concept to enable more information sharing. Common situational awareness improves port call processes.
Molkenboer, 2020	Information sharing	Analysis of information sharing between the stakeholder in planning domain of nautical services. Critical areas between planning departments are identified.
Nikghadam et al., 2021	Information sharing	Identified important information links between stakeholder in the PoR.
Wijma et al., 2018	Information sharing	Sharing information can reduce waiting times with 35%.
Vieira et al., 2015	Port logistics	Identifies a disfunction of information flow during a port call in port of Santos (Brazil).
Michaelides et al., 2019	Port call analysis	Analysis shows a poor performance from agents in terms of punctuality and utilization.
Lokin, 2022	Port call optimisation	optimisation of vessel arrival can reduce the total emissions but increases the total time in system.
Poulsen and Sampson, 2020	Port call optimisation	Turn-around time can be improved with port call optimisation. Complex due to the amount of actors involved.
IMO and Roumelioti, 2022	Port call optimisation	Optimizing the vessels voyage speed can reduce up to 14% of fuel consumption. To enable this close collaboration between shipping lines, ports and terminals is needed.
Imset, 2021	Port digitisation	One port was more keen on collaborating and participating in developing digital platforms than the other port. Afraid of mis-used of data.
Van der Lugt et al., 2015	PA strategy	More autonomy and business-like structure in PAs widens the strategic scope and brings in more business-like goals.

3

Methodology

In this chapter the Methodology of this research will be described. Several methods have been used to explore the importance of factors when evaluating innovations for the port call process. The goal is to compare the importance of proposed performance attributes between various ports. For this reason, several ports are selected as case studies. Furthermore, the steps of MCDM from chapter 2 will be used as a guide through the methodology. The Bayesian BWM will be used to determine the importance of the decision-making criteria.

3.1 Cases

To reach to the goal of this thesis six ports have been selected as case studies. When choosing six ports as case studies, the differences between ports in terms of port call processes should become evident. The case study descriptions are described in the first step of the MCDM. The descriptions will include the port call process and the relevant content factors explaining the port's environment. Describing the port call processes and reaching out to all the stakeholders involved is a time-consuming task for six ports. This is where the field expertise from KOTUG International plays an important role. KOTUG has many years of experience in international ports with many good contacts around the globe. Due to the time-consuming task, it is important to have good connections with the stakeholders involved. On top of that in the book of Yin, 2003, he mentions it is important to have access to data when selecting a case study. Thus potential ports are considered when KOTUG has good connections in the port. The following list are ports where KOTUG is either active in tug operations or where they have good contacts. This list is first of all considered as potential ports.

- Port of Sydney
- Port Hedland
- Port of Hamburg
- Port Ras Al-Khaimah
- Port of Valencia
- Port of Port Arthur
- Port of Singapore
- Port Antwerp-Bruges
- Port Tanger-Med

These ports are varying in terms of cargo, volumes, geographical and organisational structure. The ports also diversify in terms of the continent they are located in. It is expected that the port call process in one port is differently organised than in the other. Each country has its own rules and ways of working which leads to differences in organisation. The differences in organisation of a port call and what the preferences are for port call innovations will be explored in this thesis. The preferences of the stakeholders involved in a port call will be gathered before designing innovations for optimisation. Having access to contacts for interviews is thus the most important aspect when selecting the final six case studies. This is also in line with the suggestions of Yin, 2003, for choosing a case study. Secondly, it is preferred that the ports differ in terms of size, industries, and organisational structure, as mentioned earlier. In the literature section 2.3, several factors have been identified in literature to affect the port

call process. For example, a port that is centralised and a port that is decentralised. Larger ports with more stakeholders and industries will be complex. The more complex the ports are, the more diverse the preferences can be. Ports with good communication bonds ports with less good communication bonds. It would also be preferred to have ports differ in those mentioned factors.

From the 9 proposed ports above, 6 will be selected as case studies. The 9 proposed ports all have sufficient port calls per year to have an interest in port call optimisation. Either there is a need for optimisation, because there is congestion during peak hours or there is simply room for improvement during a port call. The lowest number of port calls is in Sydney bay Botnay with 1600 port calls per year and the highest is in Singapore with 130,000 port calls per year. Keeping the performance attributes from above in mind, the 6 mentioned ports below have been selected. Each port has unique characteristics and its own way of working. There is enough variation in port factors that explain the port's environment. These case studies are most accessible for interviews and surveys later in this thesis. KOTUG has good connections with the ports. For these reasons, the six chosen ports are suitable case studies for this thesis. It is most important that all nautical services of port call stakeholders are incorporated in the research to get a full and equal perspective.
The chosen ports:

- Port of Sydney
- Port of Hamburg
- Port Ras Al-Khaimah
- Port of Port Arthur
- Port Antwerp-Bruges
- Port Tanger-Med

3.2 BWM Multi-criteria Decision Making

The goal of this research is to identify the preferences for innovations for port call management in various port contexts. To reach this goal the method of MCDM is chosen. The literature review (section 2.2) has justified the MCDM to be a suitable method for reaching the research goals of this thesis. The MCDM can be distinguished by the methods for determining the weights of the attributes. Section 2.2.2 in the literature review justifies using the BWM as method for determining the weights of attributes. This thesis will focus on the MCDM aspect of determining weights. Usually, in MCDM the alternatives are created without the involvement of the stakeholders. Due to the complexity and new nature of this problem, it is preferred to focus on identifying attributes and their weights. This is a similar approach to the thesis of Schutte, 2020. She used value-focused thinking as a decision-making method that begins with achieving values to create relevant and better alternatives at a later stage (Keeney, 1996). The values of stakeholders are their objectives. This thesis will not follow exactly the same procedure due to time restrictions. For filling the proposed research gaps it is not necessary to follow all the steps of the MCDM. Figure 3.1 illustrates the steps of the MCDM Methodology. This thesis is interested in identifying the relevant attributes and the weights of these attributes.

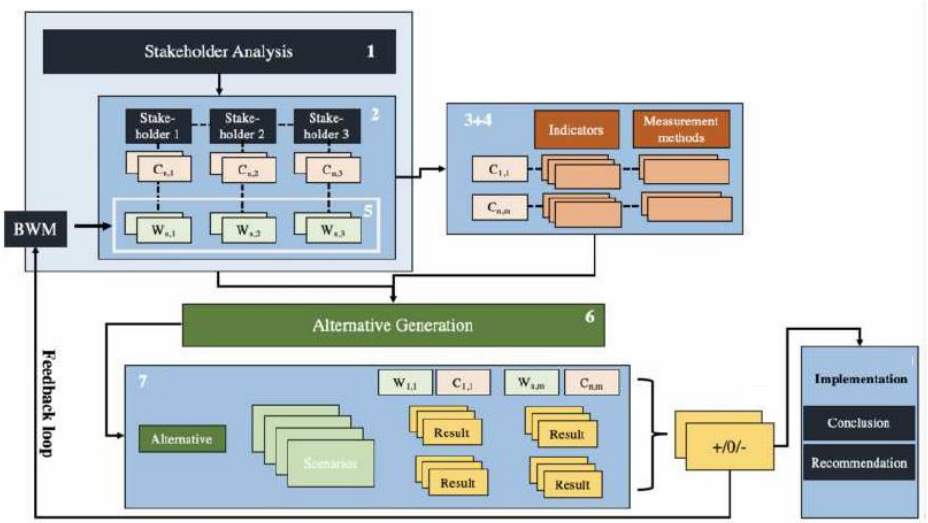


Figure 3.1: Research methodology framework (Macharis and Bernardini, 2015)

The methodology of this this thesis can be described in three steps. Figure 3.2, illustrates the steps and corresponding methods.

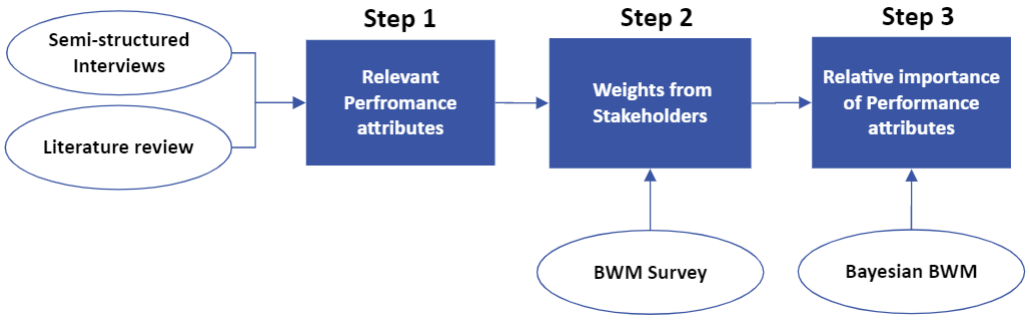


Figure 3.2: Methodology steps

3.2.1. Step 1: Identify relevant performance attributes

The second step is to identify the objectives of the stakeholders involved. This step will result in a complete list of objectives from all the stakeholders. They are not ranked or prioritised. For collecting the objective, literature Research and semi-structured interviews will be used. The proposed questions and techniques for the interviews will be from Keeney, 1996. He proposes several techniques to collect the objectives from interviews. The steps will be explained in the following sections.

Semi-structured interviews

Semi-structured interviews are conducted to understand how the port call is organised and to identify what their objectives are. First of all, the interviewees are questioned about their port call processes and their role in efficiently berthing a vessel. Questions are also asked about the port factors that may affect the port call. Multiple interviews from different perspectives will give a good understanding of the way it is organised. As mentioned in literature, each port is uniquely organised. This information can be used for the first step in the MCDM and for understanding what port factors could influence port call optimisation. Secondly, the interviewees are questioned about their objectives and goals during a port call. Their objectives will be used as performance attributes for port call innovations. It can be difficult for a stakeholder to identify all his objectives during an interview. A few techniques from Keeney, 1996 will be followed to stimulate the identification of possible objectives. Examples of some questions are: *what do you want? What do you value? what should you want? what is a perfect innovation, a terrible innovation, some reasonable innovation?*. Lastly, there are questions about their vision on optimal port call innovations. A full overview of the structure of the interview is found in Appendix B. In this research semi-structured interviews are preferred over unstructured or structured interviews. Semi-structured interviews give the interviewee time to express their views and values. Some of the questions are prepared to ensure some sort of structure. This structure fits the goal of the interviews, to allow the stakeholders to express their interests and values toward an optimal port call.

The interviews will be collected with one representative of each involved party in the port call process. This is a time-consuming task as all stakeholders have to be interviewed for 6 ports. If one representative is not sufficient for the data needed then always a second interview can be planned. The plan is to approach the harbour coordinator, tugboat company, pilots, linesmen, terminal, of each port. This means about 5 to 6 interviews per port. The number of interviews can however vary if, for example, the port authority is responsible for the nautical services. In this case only 1 or 2 interviews are necessary. It is preferred to interview someone from a more operational or strategic position in the company. The supervising company KOTUG has the resources to reach out to the right person. The interviews can be held through online meetings with MS Teams.

Expert Knowledge and Literature study

During interviews, the interviewees are not always able to generate all the objectives that are important according to a study (Bond et al., 2008). For this reason, it is important to reflect on the interviews beforehand and afterward. Expert knowledge will be found within the KOTUG company and supervisors within the TU Delft on similar topics. The benefit of researching 6 case studies is that stakeholders with similar responsibilities (however not fully) are interviewed which can lead to an extensive and complementary list of objectives. On top of that literature review can help with identifying possible attributes of MCDM. The identified attributes from literature can be found in section 2.3.4. All in all, the result of this section will be a comprehensive list of objectives that will be sorted per stakeholder and structured in the following step.

Structure the attributes

After identifying the possible attributes, they should be structured. The attributes from the interviews will be gathered and clustered. Attributes with similar effects will be clustered. If an attribute is mentioned twice or more then it is clustered and used. The most relevant and most mentioned attributes will be considered. For a comparative analysis of the preferences between the ports the selected objectives need to be similar throughout all ports and stakeholders. Meaning the extended list should be relevant and understandable for all stakeholders. When sorted, objectives can have different hierarchical-level: fundamental objectives and means objectives (Keeney, 1996). Fundamental defines why a stakeholder is interested and a means objective describes a mean to achieve the fundamental objective. Keeping in

mind that, a maximum of 9 attributes and a minimum of 3 attributes can be selected for the BWM in a single set. The attributes will have to be sorted in a two-level structure. Within a level, the attributes should be on the same hierarchical level. For example, performance and sailing speed cannot be on one level. Sailing speed is an attribute that could explain the performance.

3.2.2. Step 2: Collect weights with BWM Survey

Receiving pairwise comparisons from the decision-makers will be done through a survey. The survey will be sent to the decision-makers after the round of first interviews. These are stakeholders who play a dominant role in port planning. They have a more operational, commercial, or strategic role in their organisation. The survey will be sent to the same contacts as the first interviews. The first contact has been already made thus the response rate should be fairly high. In the contact mail, it will be asked to further distribute the survey to 1 or 2 colleagues for a higher response rate. This could increase the confidence levels of the credal rankings. If all stakeholders respond to the survey, about 5 to 6 respondents, with different roles, from each port can be gathered. This could lead to a good analysis between ports. There is no minimum amount of respondents necessary but the more the stronger the analysis. If there are enough respondents an analysis between groups can be done. For example, how do the tug operators generally score attributes compared to port authorities?

The respondents will be asked to select a best and a worst attribute out of the proposed performance attributes. Once they have selected a best and worst, it is asked to score the best attribute against the rest and the rest of the attributes to the worst. As the selected attributes have two hierarchical levels, this must be done for the main level and each performance attribute. An example of the survey is presented in appendix E.

3.2.3. Step 3: Relative importance of performance attributes with Bayesian BWM

The Best-Worst Method (BWM) is a tool to determine the weights of the performance attributes corresponding with the values of the decision-maker. The weights of the performance attributes can be used to eventually solve the MCDM problem. In this thesis, the BWM can find the relative importance of the proposed performance attributes. The foundation of the BWM is based on pairwise comparisons where each decision-maker gives a direction and a strength of the preference i over j.

As explained in the literature review there are several methods for getting weights for the performance attributes. The regular BWM performs significantly better than the AHP in terms of consistency and conformity. The BWM is also good at mitigating the possible anchoring bias during the process of pairwise comparisons. In this research, the regular linear BWM and the Bayesian BWM will be used to determine the weights of the performance attributes. The regular is used for individual responses. The Bayesian BWM is a suitable method as it can find the optimal weights based on the preferences of group decision-makers. When finding the optimal weight for several decision-makers, the aggregated average is sensitive to outliers and provides restricted information regarding the overall preferences of all decision-makers.

The Bayesian hierarchical model is suited for K decision makers, each k decision maker evaluates the objectives $c_1, ..., c_n$ by providing vectors A_B^k and A_W^k (Mohammadi and Rezaei, 2020). The aggregated optimal weight is presented by w_agg. w_agg is computed based on the optimal weights of K decision-makers shown by w^k. Figure 3.3, shows a graphical representation of the Bayesian hierarchical model. The two circular nodes are variables that need to be estimated. The arrows denote that the node in the origin is dependent on the node at the end. Thus, the w^k is dependent on the provided A_B^k and A_W^k, and the value for w_agg is dependent of the w^k.

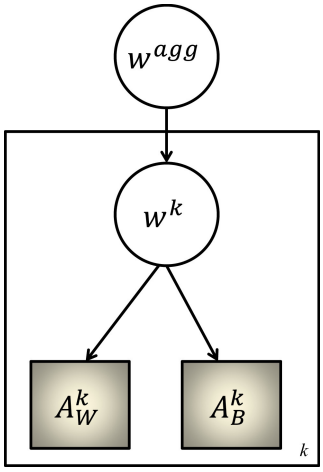


Figure 3.3: The probabilitistic graphical model of the Bayesian BWM (Mohammadi and Rezaei, 2020)

The input of the Bayesian BWM is the same as the original BWM. To conduct the linear model of the BWM 5 steps are to be followed Rezaei, 2015. For the Bayesian BWM, the fifth step uses probability distributions and a hierarchical model instead of averages and a linear min-max problem (Mohammadi and Rezaei, 2020). Steps 5 is for the linear model of BWM and Step 6 is for the Bayesian BWM.

1. Determine the set of decision criteria. In this step, the criteria $(c_1, c_2, ...c_n)$ are considered for decision-making.
2. Determine the best (most desirable or important) and the worst (least desirable or important) criteria. The decision-maker identifies the best and worst criteria in general. No comparison is made in this step.
3. Determine the preference of the best criterion over all the other criteria using a number between 1 and 9. 1 indicating equal importance and 9 indicating extremely more important. Resulting in a Best-to-Others vector:
$$A_B = (a_{B1}, a_{B2}, ..., a_{Bn}), \tag{3.1}$$
where a_{Bj} indicates the preference of the best criterion B over criterion j.
4. Determine the preference of all the criteria over the worst criterion using a number between 1 and 9. 1 indicating equal importance and 9 indicating extremely more important. Resulting in a Worst-to-Others vector:
$$A_W = (a_{1W}, a_{2W}, ..., a_{nW})^T, \tag{3.2}$$
where a_{jW} indicates the preference of the criterion j over worst criterion W.
5. Find the weights $(W_1^*, W_2^*, ..., W_n^*)$ for the individual respondents. This is done by minimising the maximum absolute differences, with the non-negativity condition for the weights and the sum of all weights equal to 1. The following min-max problem is formulated:
$$minmax = |w_B - a_B j w_j|, |w_j - a_j w w_W| \tag{3.3}$$
s.t.
$$\sum_j w_j = 1 \tag{3.4}$$
$$w_j \geq 0, \forall j \tag{3.5}$$
This model can be rewritten to the following model:
$$min\xi \tag{3.6}$$
s.t.
$$|\frac{W_B}{W_j} - a_B j| \leq \xi, \forall j \tag{3.7}$$

$$|\frac{W_j}{W_W} - a_j W| \leq \xi, \forall j \tag{3.8}$$

$$\sum_j w_j = 1 \tag{3.9}$$

$$w_j \geq 0, \forall j \tag{3.10}$$

6. Find the aggregated weights $(W_1^*, W_2^*, ..., W_n^*)$ and the weights for each decision-maker $w^k, k = 1, ..., K$. K being the total decision-makers in one set. The weights are obtained with the following probabilistic functions (Mohammadi and Rezaei, 2020):

$$A_B^k | w^k \sim multinomial(1/w^k), \forall k = 1, ..., K \tag{3.11}$$

$$A_W^k | w^k \sim multinomial(w^k), \forall k = 1, ..., K \tag{3.12}$$

$$w^k | w^a gg \sim Dir(\gamma x w^a gg), \forall k = 1, ..., K \tag{3.13}$$

$$\gamma \sim gamma(a, b) \tag{3.14}$$

$$w^a gg \sim Dir(1) \tag{3.15}$$

Equations 3.11 and 3.12 use multinomial distributions to model A_b and A_W. Equation 3.13 says that the weight vector w^k of each decision-maker must be in the proximity of $w^a gg$ since it is a mean distribution and their closeness is governed by the non-negative concentration parameter *gamma*. Equation 3.14 models parameter *gamma* with the gamma distribution. Equation 3.15, uses an uniformative Dirichlet distribution with parameter $\alpha = 1$.

When conducting a BWM it is good to acknowledge that one BWM only allows for a maximum of 9 attributes (Rezaei, 2015). It is preferred to conduct multiple BWM in case of a hierarchical order of attributes. However multiple BWMs will require more time. This is an important trade-off to think about when selecting the set of attributes. A BWM finds the optimal weights of a set of attributes based on the preferences of only one decision-maker (Mohammadi and Rezaei, 2020). To reach an aggregated weight of multiple decision-makers arithmetic or geometric mean can be used. The downside is that averages are sensitive to outliers. Another drawback of the BWM is that there is a high likelihood of biased information when gathering data. Data is purely reliant on the perspective of the stakeholders. However, validation of the collected data is very difficult. Another drawback of the BWM is the possibility that stakeholders don't execute the steps correctly. The set-up of the survey can play an important part in collecting reliable data.

Credal ranking

If one averaged weight attribute is higher than another attribute in the MCDM, it can be said that one attribute is more important than the other. Assume three attributes with weights (0.49, 0.50, 0.01). According to the MCDM, the second criterion is superior to both the first and third. However, the confidence of the superiority cannot be determined by solely comparing two weights. Credal ranking can calibrate the degree to which one criterion is superior to the other. The posterior distributions of weights help gauge the confidence of the relations between various attributes. A value of 1 will indicate full confidence that one is superior to another. A threshold value above 0.5 can indicate attribute c_i is more important than c_j. Determining the confidence of superiority is even more important when the weights represent a group of decision-makers. Further explanation of the credal ranking can be found in the paper of Mohammadi and Rezaei, 2020.

4

System Description

This chapter describes the system studied. For this thesis, the processes of the port call in various ports are the system. This chapter starts with organisation of ports, Then describes the general processes of a port call and the stakeholders involved. The last section concludes with the specific port cases studied.

4.1 Organisation of ports

The large logistical hubs called ports are often organised in different ways depending on their environment. In literature, the organisation of ports has been classified into the model by the World Bank (Foulquier and Maugeri, 2012). Which describes the responsibilities of the PA. The 4 roles are Service Port, the Tool Port, the Landlord Port, and the Private Service Port. These roles differ in the ownership of infrastructures, superstructures, operations, and in the provided service, seen in table 4.1. Infrastructure refers to the roads and rails to the port. Superstructure refers to the equipment and buildings. Port labour refers to workers at ports. Other functions refer to ancillary activities like towage, pilotage, and linemen. For example in a port like Rotterdam, the port authority has a landlord model, they are only responsible for the investment in infrastructure. The other activities are privatised.

Table 4.1: World Bank Port Management Structures

	Infrastructure	**Superstructure**	**Port Labour**	**Other functions**
Public service	Public	Public	Public	Public
Tool	Public	Public	Private	Public/private
Landlord	Public	Private	Private	Private
Private	Private	Private	Private	Private

This model is important as it is the only model in literature that describes the management of a port. The management model could determine how the port call is managed. According to the literature reviewed in chapter 2 the port call management could differ per port case.

4.2 Port Call

To begin it is important to define a port call. The port operations of berthing a vessel are also referred to as port call processes. Lind et al., 2015, refers to it as the activities performed prior, during, and after the voyage of a sea vessel.

4.2.1. Port Call stakeholders

For an understanding of the port call, it is important to know which stakeholders are involved. In this section, an overview of the stakeholders involved together with their responsibilities will be presented. The processes and stakeholders involved have been mapped by several studies. Nikghadam et al., 2021 & Molkenboer, 2020, distinguishes port call stakeholders and nautical services. Port call stakeholders are all the stakeholders involved during a port call. This includes the captain of a vessel, vessel agent, shipping company, port authority, pilot, tugs, linemen, terminal, and vessel services. Their responsibilities are further described in table 4.2. Nautical services are referred to as the services on water, the tugs, linemen, and pilots are part of this. The nautical services closely work together to safely manoeuvre the vessel into the port. The order of stakeholders presented in table 4.2, is random and does not reflect a hierarchical order. During the port call process, the pilots have a critical position in the manoeuvring of the vessel and the other nautical services often follow Nikghadam et al., 2021. The actor analysis, derived from Wijma et al., 2018, and Molkenboer, 2020, shows that the actors: captain, vessel agent, shipping company, and terminal are more involved in the planning steps of a port call. The processes of a port call can be explained in various stages, this will be done in the following section. Depending on the stage analysed various stakeholders are relevant. The amount of stakeholders involved depends much on the choice of the scope by the author. For this thesis, the scope is limited to the key stakeholders mentioned in section 1.4 based on the port call process.

Table 4.2: All stakeholders in a Port Call

Stakeholder	Responsibility
Captain of Vessel	Responsible for well-being of ship and crew. Always has full authority over his ship.
Vessel Agent	Captain communicates through the Vessel agent. He has administrative responsibilities and notifying the port upon arrival of the vessel. Other activities like communication with the terminal, requesting nautical services, and customs of cargo also fall under his responsibility.
Shipping Company	The shipping company is owner of the vessel and offers the route a vessel sails. The shipping company usually has influence on the upfront planning of ports its going to visit. During the port call itself the vessel agent is in the charge. The large shipping companies often own or have interests in terminals giving them a lot of power on terminal operations.
Port Authority	Is the owner of the port. Two divisions are relevant for the port call, Harbour Master and Vessel Traffic Service (VTS). The harbour master is concerned with the port call planning and advises parties in the port. VTS is responsible for safe passage through the port. VTS has direct contact with the captain or pilot.
Pilot	Board the vessel to safely manoeuvre in and out of the port. Pilots gives instructions to the captain and tugs about the vessel's movements.
Tugs	Responsible for safe and agile manoeuvrability of the vessel in the port area and assisting the vessel to berth.
Linemen	They are responsible for mooring the vessel to the quay.
Terminal	Responsible for loading and unloading the cargo of a vessel. Terminal is a transshipment hub for goods. The terminal work closely with the vessel agent before berth to update the ETAs of the vessel.
Vessel services	Several parties that provide the vessel with needs such as bunkering, provisions, and maintenance.

4.2.2. Port Call Processes

The port call processes have been mapped by several (Lind et al., 2016; Nikghadam et al., 2021; Vermeulen, 2020; Wijma et al., 2018). Lind et al., 2016, has mapped the processes for a general port of bulk and container cargo. The other three studies have mapped the processes for the PoR. There is no other literature describing the port call processes. Processes of the port call, besides the PoR, have not been studied. The port call processes can be described as the steps prior to and after the berth of a vessel in a port. In other words, manoeuvring a vessel into and out of a port. The moment the pilot boards the vessel until the vessel leaves the port's gateway, is referred to as turn-around time in most research studies (Poulsen and Sampson, 2020;Wijma et al., 2018). This excludes the waiting time outside the port. This in turn influences how long vessels wait at anchorage. It can thus be argued that the turn-around time should start when vessels arrive at anchorage. This way you also incorporate a full picture of the port performance. This thesis will understand the port call from the moment the vessel first makes contact with the VTS until the vessel leaves the VTS range again.

To get an understanding of the processes the metro map of Lind et al., 2016, describes it well (figure 4.1). It is important to mention that these are the steps for a generalised port call process. As Lind, Ward, and Bergmann, 2020, quotes: 'One size does not fit all'. Meaning the general description of the

port call processes can be different for different ports.

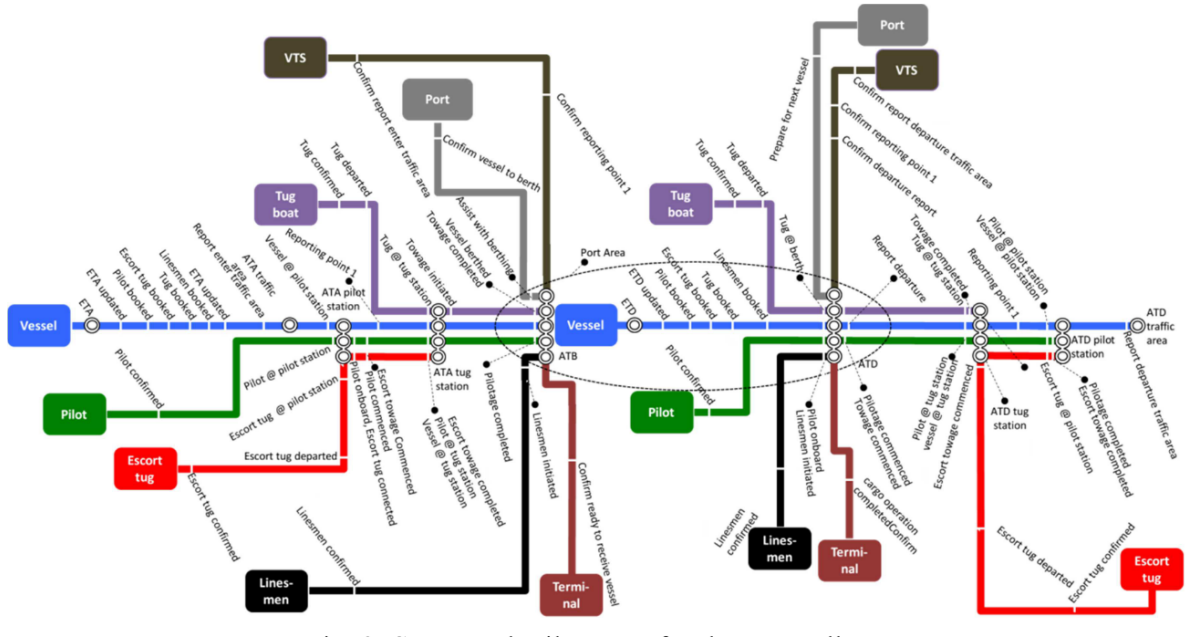


Figure 4.1: Detailed Port Call Process represented in Metro map Lind et al., 2016

The International Taskforce of port call optimisation published an information manual for the standardisation of data (2018). The terminology from this manual will be used in this thesis. The process usually starts before the voyage, known as the berth planning, with the vessel agency planning berth location and a time window at a terminal. The vessel agent is responsible for all administrative tasks of the cargo. This planning can vary from a year in advance to sometimes 24 hours in advance. This depends on the contracts between the terminal and shipping agency and the schedule of the terminal. The terminal planning is the leading planning in this process because without a berth place there is no port call (IMO, 2020b). After confirmation from the terminal, the vessel agent can plan the voyage based on the requested time of arrival (RTA). A vessel agent can receive multiple RTAs. When both the vessel agent terminal has planned the voyage, the RTA will be confirmed and become a planned time of arrival (PTA). The berth planning can also be between a vessel agency and a port planner. A port planner knows several faces, it is usually the Vessel Traffic Service (VTS) or the Harbour Coordination Center (HCC) During the vessel's voyage, the PTA can differ from the ATA because it is dependent on the ATD berth of the previous vessel. So a PTA can not always be reliable due to previous delays. Nevertheless, the PTA is the data that should be leading in the operations for the nautical services. This can be seen as the input to the nautical planning. About 48 - 3 hours before ETA the vessel is responsible for updating the port authority on their ETA at Pilot Boarding Place and book the nautical services. This is part of the port planning. The nautical services are sometimes dependent on the contract between carriers and service companies. Not all nautical services serve a certain incoming vessel. Some ports also have a harbour coordinator which can give future advice to the PA about ETAs.

Based on the ETA of the vessel the port planning can be made by the harbour coordinator center (HCC) from the port authority, if they have one. Otherwise, the port planning is determined by the Vessel Traffic Service (VTS). This is referred to as the port planning. If the port authority gives clearance then the vessel is allowed to come into the port. The harbour coordinator is then the consultative party for the arrival and departure process of vessels within the port. About 12 to 3 hours (this depends on the rules of the port) prior to the ETA the vessel agency makes contact with the VTS operator or the terminal. The incoming vessel will already be known at the port authority but will update its ETA if necessary. The port authority or terminal usually communicates with the vessel agency and updates the status of the vessel. The vessel usually waits at anchorage before it's called to the pilot boarding place.

Then the nautical chain manoeuvres the vessel to its berth. The pilot is responsible for manoeuvring the vessel in the port area. The Pilot, Tugboats, and Linesmen should be booked by the vessel agency and they operate according to their planning. This planning is based on the PTA but when delayed each party should be updated accordingly. This doesn't always happen as it should, this will be discussed in a later section. The pilot, tugboats, and linesmen need to be in the right place at the right time to bring the vessel into the port. The activities of the nautical services need to be coordinated as they are dependent on each other. Pilots and tugs are needed about 2 to 3 hours before the ATA. The linesmen are needed about 1 hour before the ATA. The linesmen are responsible for mooring the vessel. The terminal is then responsible for unloading and loading operations. While the vessel is at berth other services can be performed like bunkering, maintenance, or a crew shift. During loading operations, the terminal releases a planned time of departure to leave the port in similar manner. Meaning a Pilot, Tug, and Linesmen need to be available for the departure of the vessel. Once the pilot has left the vessel and the vessel is no longer in range of the port's authority VTS radio, the port call is finished. Generally, these are the processes of a port call. However, the processes differ per port, below will describe processes in various ways.

Figure 4.1, is a rather complex figure to read just like some metro networks around the world. The main takeaway from this figure should be that there are many stakeholders involved during the process with lots of information being shared. These processes can be described as an intertwined chain. This network illustrates that collaboration can be very difficult due to the amount of information and interactions between stakeholders. Meaning the port call processes are rather complex and dependent on each other. If one process is delayed it has an effect on the entire chain.

4.2.3. Innovations in Port call management

The problems in port call management can be described as a two-sided problem to the same coin. On the one side vessel's unpredictability causes distributions in planned time of arrivals (Poulsen and Sampson, 2020; Broersma, 2021). On the other side, the capacity problems of the nautical services delay the operations of a port call (Molkenboer, 2020). These delays in ports harm the turn-around time of vessels and thus the port's performance. Currently, several innovations are being designed to improve operations in port call management. Different tools and concepts are being designed to enhance data sharing and collaboration during a port call. Some tools and concepts from the industry will be described below to get a grasp of possible innovations that could improve some of the challenges. For decision-makers to give their preferences on performance attributes for evaluating innovations, it can help to have an idea about the possible design of innovations. These innovations are derived from literature and digital port conferences visited.

PortCDM

The most dominant concept in literature is Port Collaborative Decision Making, in short PortCDM. It was introduced as a concept of Sea Traffic Management to facilitate collaboration with the goal of optimising port visits and reducing turn-around time (Lind et al., 2018). PortCDM was inspired by the aviation sector, to shorten flight times, reduce environmental footprint and enhance precision on arrival and departure times. The PortCDM concept enables all stakeholders to share real-time data about events during a port call. Stakeholders are automatically informed about an update instead of one agent being responsible. Lind et al., 2018, describes PortCDM as a facilitator for collaborative dynamics for port call coordination (internal collaboration) and synchronisation (external collaboration). Port call synchronisation is aimed at the continuous coordination of vessel operations, from port to port coordination. Port call coordination is more aimed at the alignment of internal processes. This thesis is focused on the port call coordination of PortCDM. Currently, information sharing is typically a chain of stakeholders often communicated through the phone. The risks are that the information is not always shared. A PortCDM should break this chain and ease communications. A common situational awareness is seen as the biggest feature of a PortCDM concept. The concept could solve problems like changes not communicated and straightforward, efficient communication (Lind et al., 2019; Wijma et al., 2018). A data-sharing tool could be an example to facilitate PortCDM.

Portxchange
Portxchange is one example of a data-sharing tool to promote PortCDM and thus port call operations. Portxchange is a centralised platform for sharing real-time data to align all players in the port call. Sharing real data avoids delays and makes port calls more predictable, efficient, and sustainable ("PortXchange", 2021). The platform improves collaboration for all involved stakeholders by having a single point of information. The benefit is that everybody has common situation awareness. The stakeholders are notified on the activities when there is a status change or a conflict in the process. These notifications should help the involved stakeholders have situational awareness. The application does not actively schedule or make decisions in the port call. It is still up to the stakeholders themselves to make decisions.

Port Community System
A Port Community system (PCS) is active in most of the ports. The goal of the port community system is to reduce administrative burdens and decrease the paperwork during a port call. The PCS can be defined as a centralised port information and data hubs that integrate and distribute data from different parties Tijan et al., 2021. The functions of the PCS will differ per port and depends on the willingness to use and share data. Yavuz, 2011, distinguishes three functions: the port management functions, customs function, and online platform for electronic commerce between port users. An interviewee also mentioned that a good PCS is the starting point for collaboration in a port (appendix B).

Optimised asset utilization
The port call can be improved by optimising the scheduling of assets in such a way that assets are optimally utilised. Currently, all the involved stakeholders are planning their activities individually and by hand. Individual stakeholders could use artificial intelligence to assist with smart port call planning. An example of this is the tool Optiport developed by KOTUG, to optimise a tug schedule. Seen as tugs are often a capacity bottleneck, such an application helps with the allocation of tugs smartly. This then improves the port call. A brief description of the optimal planning tool will be presented to get an understanding of how it works.

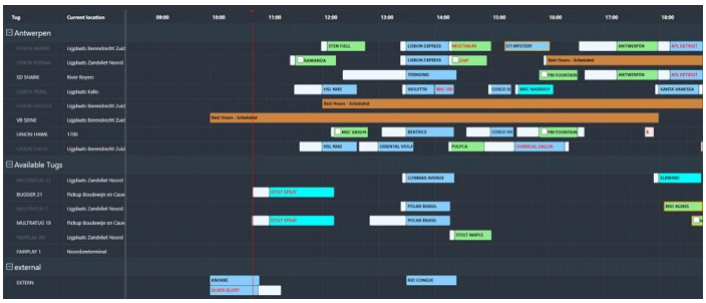


Figure 4.2: Optiport Interface

Optiport can be described as a schedule optimiser that uses machine learning and intelligent algorithms to optimise the schedule of tugboats. The interface is a Gantt Chart, illustrated in figure 4.2, showing the job tasks of each tugboat over time. Optiport uses static (like: port infrastructure, fleet info, crew info, nautical info) and dynamic data (like: Job data, AIS data, Weather, Tidal data) to calculate and present an optimal schedule for tugs. Figure 4.3 illustrates this, in the middle of this schematic overview the steps are presented. AIS Data contains data about the vessel's position, course, and speed.

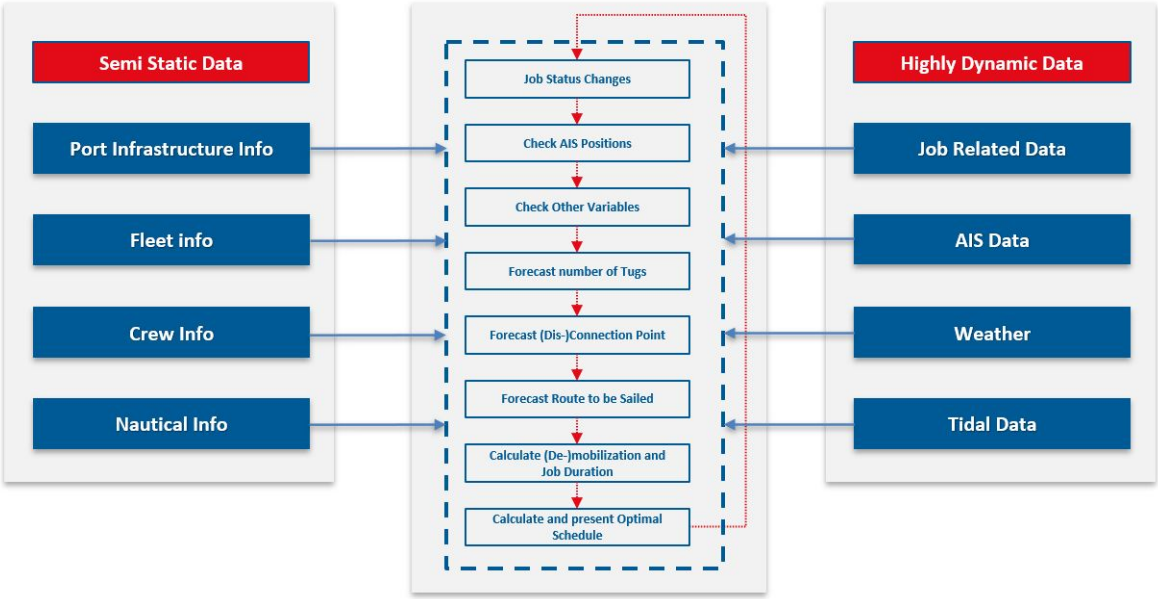


Figure 4.3: Schematic overview of steps behind Optiport

Optiport is an example of a tool that schedules tugs. Other tools can optimally schedule other assets to bring improvements for other stakeholders. The result is that each stakeholder is optimising processes on their own. On top of that many different tools have to be integrated. This leads to sub-optimal results where all stakeholders act in their own interests. To reach a system optimum, an optimised port call scheduler could be designed. This would mean that the activities are centrally planned and the planning is optimised over the entire system instead of individual interests. Theoretically, this is already possible with the optimisation tools. However, it is unclear how to optimise this and what interests to optimise. This thesis can give insights into what the different interests are in various ports.

4.3 Port cases

During the interviews with various stakeholders from the studied ports, an understanding of port call management is created. The way a port call is managed is described for each port in appendix C. From these descriptions, the following is concluded. The complexity in terms of the number of stakeholders, industries, and port calls often determines the complexity of the port call. The higher the amount of stakeholders involved the more interdependencies there are and the more difficult port call management becomes. Also, multiple industries in one port can make a port call more complex as there are more industries with different needs. For example, the frequency of arrivals for bulk is more scattered than for containers. Liquid bulk tankers often visit more than one terminal in a port requiring several manoeuvres in a port. The amount of port calls logically makes a port call easier or more difficult in terms of traffic management. Furthermore, the role of the port authority and its management structure influences the organisation of the port call. This is in line with the findings of Lind, Ward, Bergmann, et al., 2020 & Van der Lugt et al., 2015.

The factors affecting the way port calls are managed have been identified during the interviews with stakeholders in the port cases. There are 5 factors that distinguishes the working of the port call in the studied ports. These factors are: Management, Role of the PA, Number of stakeholders involved, Industries, Number of port calls, Nautical restrictions. The six studied ports all differ from each other. The full descriptions of the port cases can be found in appendix C. Table 4.3 summarises these port factors for the studied ports.

The first factor is the management structure, this can be either centralised or decentralised. A centralised management means the processes are organised by a single entity. This gives a lot of transparency and good internal coordination. RAK Ports is a good example of a centralised port. The other studied ports are managed decentralised.

The second factor is the role of the PA, if the PA takes on more responsibilities, they have more control over the processes in a port. If a PA takes all responsibilities in a port it can be classified as a service role by the World Bank Tool as explained in section 4.1. This means that all assets and land are owned and operated by the PA. The Port of Port Arthur can be classified as a private model because there is no PA active in the port. Port of Sydney and Port Tanger-Med have a landlord model however the PA has a more active role in operations.

The third factor is the number of stakeholders involved during a port call. For the port of Port Arthur there are the most stakeholders as there are many different terminal companies. Antwerp-Bruges is a bigger port but has bigger companies with several terminals. The more involved stakeholders, the more interactions and interdependencies during a port call. It is also probable that different stakeholders also have different values, making it difficult to align interests. The interests will be studied in the following chapters.

Furthermore, the fourth factor is the industry types a port offers. The different industries are containers, dry-bulk, liquid bulk, break-bulk cargo, and passengers. A combination of different industries can have an influence on the frequency of arrivals and the number of shifts within a port. Thus a multi-industry port is more complex than a single-industry port. Ports: RAK Ports and Port Tanger-Med are examples of single-industry ports.

Lastly, the amount of traffic and nautical restrictions are port specific and can force ports to adopt measures to improve the port call processes. The nautical restrictions are often the biggest influence of complexities during a port call. These specific restrictions are specific to the port. Port Antwerp-Bruges, Port of Hamburg, and Port of Port Arthur are examples of ports with complex nautical restrictions.

From the interviews held it can be concluded that not all ports are eager or have the need to optimise their port call. For example, Port of Sydney has enough capacity to handle current demand. They have also already implemented some innovations like advanced weather forecasting. At this moment in time, there was no need to implement innovations to improve port call management. RAK ports has one central authority, one commodity, and a low number of port calls per year. They already have a high internal coordination. There is less necessity to optimize the port call as only one vessel enters at a time. The port call process is not a bottleneck in this port. On the opposite side, the Port of Hamburg has much more interests to coordinate due to the narrow gateway. This port has a coordination center to advise the PA with the planning of the port call process, by collecting all the information the port

call can be planned further in advance. According to the interviews, such measures improve the port call process and keep all stakeholders informed. These examples give a good understanding of how the port calls work and how they differ in terms of organisation and processes. The different environments that the ports have will most probably also lead to differences in performance attributes and preferences of these attributes. It will be interesting to see if there is heterogeneity or homogeneity in the way performance attributes are weighted by stakeholders. This will be explored in the following chapter.

Table 4.3: Overview of port contexts

	Management	**Role of PA**	**No. of stake-holders**	**Industries**	**Port calls**	**Nautical restrictions**
RAK Ports	Centralised	Service	1	Dry-bulk	1700	Tidal Windows
Port of Hamburg	Decentralised	Landlord	10-20	all industries	10000	Narrow & Long river, Tidal windows
Port Antwerp-Bruges	Decentralised	Landlord, service	10-20	all industries	13000	80km inland, Locks, Tidal windows
Port of Port Arthur	Decentralised	Private	20+	liquid-bulk & break bulk	6400	Long river, spread out terminals, Day-light restrictions,
Port of Sydney	Decentralised	Landlord*	6	Dry- & liquid-bulk & containers	5800	Very few
Port Tanger-Med	Decentralised	Landlord*	6	Containers	10000	Very few

* The general structure of the PA is a landlord model, however the PA takes a more active position by operating the pilotage and licensing the tugs. Could be described as a hybrid of landlord and service role.

5

The performance attributes for evaluating innovations

This chapter will present the performance attributes for evaluating port call innovations. These performance attributes are collected during interviews and then sorted into three categories. Table 5.5 gives a overview of the relevant attributes. This chapter also answers sub question 1.

5.1 Performance attributes from literature review

As mentioned in the literature review, there is a gap in the literature about relevant attributes for evaluating innovations in port call management. The study of Lokin, 2022, has reported the optimisation objectives for each actor in the port call process. The stakeholders have different optimisation objectives, as seen in table 5.1. Not all objectives can directly be used as performance attributes of innovations for port call optimisation. There is no further research into relevant performance attributes for port call optimisation. For this reason, the relevant performance attributes must be captured through interviews with various stakeholders. It will be interesting to see if the mentioned attributes show similarities with the reported objectives below.

Table 5.1: optimisation objectives (Lokin, 2022)

Stakeholder	**Objective**
Captain	Vessel arrival and departure without waiting time (depends on cargo type)
Nautical services	Optimal asset use and allocation
Harbour Master	Operations optimised for safety and throughput
Terminal operator	Berth utilization

5.2 Attributes from interviews

As mentioned in the previous section, the attributes found in the literature are not sufficient to directly adopted to this decision context. There is only 1 study that identified objectives related to port call optimisation but none are specifically for decision-making in port call innovations. This study is unique in identifying performance attributes for adapting innovations in port call management. For this reason during the interviews questions were asked about what criteria the stakeholders find important during the port call process.

Keeney, 1996, mentions that the objectives for a decision context should come from the individual involved and should be knowledgeable about the subject. For this thesis, interviews with various stakeholders from the port call have been conducted. The interviewees are representatives of different involved stakeholders in the studied ports. The decision-makers of a port call innovation can be considered as the PA, Pilots, Tugs, Linesmen, and Terminals. These are the most dominant stakeholders in the port call process. Thus for all 6 studied ports, a representative of the most relevant stakeholder is interviewed. Besides the dominant stakeholders within a port, 1 interview is conducted with a representative from a shipping company. In total 14 interviews were conducted in a period from the 17th of June to the 9th of September. Table 5.2 shows an overview of the stakeholders interviewed. For privacy reasons, their names have been left out. The full summary of each interview can be found in appendix B.

Table 5.2: List of Interviewed Stakeholders

Port	Stakeholder	Function	Date
RAK Ports	Port Authority	Group harbour master	17 June 2022
	Port Authority	Port Manager	26 July 2022
	Port Authority	CEO	25 July 2022
Port of Hamburg	Coordination center	IT Project Manager	4 July 2022
Port Antwerp-Bruges	Port Authority	Port Development	27 June 2022
	Terminal	Operations Manager	19 July 2022
	Pilots	Operations Manager	14 July 2022
Port of Port Arthur	Tugs	Commercial Manager	27 June 2022
	Tugs	Director of Operations	30 June 2022
	Pilots	Operational Manager	22 July 2022
Port of Sydney	Port Authority	Harbour Master	19 July 2022
	Tugs	Commercial Manager	28 July 2022
Port Tanger-Med	Port Authority	Port Call optimisation	9 September 2022
-	Shipping Company	Port optimisation Manager	30 August 2022

To derive the performance attributes from each interviewee, a semi-structured interview is conducted, found in appendix B. At first, a description of my research was provided for each interviewee to get an understanding. Thereafter, several questions are asked about the Port call and the organisation of the port call. Then the question was asked: 'What criteria are important to you when evaluating an innovation for the port call process?'. Some follow-up questions were asked if only one or two criteria were mentioned. This process has led to many attributes, both on a macro level and a micro level.

The performance attributes that have been identified from the interviews are analysed and sorted. The attributes mentioned during the interviews are often case-specific or stakeholder specific. For this reason, not all attributes are applicable from the interviews. For this research, it is important to have one complete set of attributes that is applicable to all stakeholders. All stakeholders in all studied ports will receive the same set of performance attributes for valuation. An attribute is added if the

attribute could be considered relevant for all stakeholders and is mentioned by at least two interviewees. During the collection, stakeholders gave various terminologies of similar attributes. This could be either because stakeholders refer to objectives or KPIs within their department or simply because different stakeholders use different terminologies. The attributes are grouped and classified under one aggregated category. Table 5.3, shows a summary of the most mentioned attributes from the interviews. In total 94 attributes have been mentioned.

Table 5.3: Summary of performance attributes from interviews

Aggregated category	**No. Mentioned**	**Attributes from interviews**
Time related processes	17	*On time operations, Time efficient, Delays, Reduction deviations to planning, Less waiting time on vessels, Delays, Deviation, Minimise delays of vessel, Time deviation of original plans, Time on board, Delay of vessel, On time arrival tugs, Servicing as schedule, On time, Turn-around time*
Operational efficiency	13	*Efficiency to maximise revenue, Amount of ships handled per year, Time efficient, Fuel efficiency, Operational efficiency, Fuel consumption, Amount of ships moved, Port call efficiency, Efficient operations, Impact on chain, Connection to workers schedule*
Safety	12	*Zero injuries, Zero fatalities, Safety, Reduce incidents, Dangerous incidents tolerance, Near miss reports*
Asset Efficiency	9	*Optimal asset allocation, quick executed operations, utilization of assets, allocation of assets, Tug utilization, Asset efficiency, Pilots as scheduled, crew utilization, berth occupancy*
Costs	8	*Costs by marine, Cost efficiency, Add value to port, revenue per job, Total profit, Capex, Opex*
System effectiveness	4	*Practical fit, Effectiveness, It should work, Purpose*
System Reliability	3	*Reliable, Reliability of suggested plans, Reliable data sharing*
User-friendliness	3	*User friendliness, Easy to use, low threshold*
Data availability	3	*Uniform access to information, Information sharing, On time data availability*
Flexibility	2	*Flexibility of your assets, Resource availability*

According to the interviewees, an innovation for the port call process should contribute to *processes being on time, efficiency,* and *safe*. Attributes related to *Time*, have been mentioned the most in interviews. It is an important aspect of the entire port call. If all stakeholders are on time and operations run according to schedule then a port call will run smoothly. The HVCC for example schedules the vessel traffic with the objective to minimise the maximum deviation of time (see interview appendix B). Typically for tug operators, on-time arrivals of tugs is important. The Terminals prefer to reduce the time deviations in their berth planning. These are the same findings as Lokin, 2022. Different stakeholders interpret time differently. However, it all comes down to processes happening on time. Attributes related to *Operational efficiency* have also been mentioned often. Operational efficiency can

be interpreted differently depending on the stakeholder. For Tugs, Pilots, and Linesmen the use of their assets is important to minimize costs. For Tugs Fuel efficiency is very important too. These attributes are focused very much on operational efficiency. This is also similar to the objectives of Lokin, 2022. The attribute *Safety* seems important for every stakeholder as it is mentioned in almost all interviews. These three attributes are mentioned the most. It is important to note that this does not say anything about the importance of these attributes. The method for quantifying the importance of each attribute has not been used in this stage. It will be interesting to see if the global BWM results will show similarities with the most mentioned attributes from the interviews. However, the next step is to classify the criteria.

5.3 Selecting relevant performance attributes

When selecting attributes, the following requirements are important: consistency, macro level, and relevance. To compare a port with other ports the set of attributes must be consistent through all ports. The same set of attributes must be evaluated by all stakeholders in all ports. This means the attributes should be interpretable for all stakeholders. The attributes should also be relevant for all stakeholders. The attributes must not be stakeholder specific because a respondent can't score an attribute 0. All attributes need to be valued compared to the worst and best attribute. For this reason, all the attributes are related to the port call chain and not company-specific attributes. The attributes are more on system level because we are interested in innovations improving the entire port call process. It is also important that the attributes are understandable for all stakeholders. Performance attributes solely from interviews are considered.

Considering these requirements not all attributes can be chosen. For example time on board, fuel efficiency, and crew utilization are attributes that cannot be chosen. Relevant attributes from top to bottom are chosen in table 5.3. A total of 17 attributes have been chosen to be relevant. They are considered relevant because they are mentioned often and meet the requirements. For background information on the selection process appendix D should seen. Table 5.4, presents a list of the 17 attributes.

Table 5.4: Selected attributes

Selected attributes:
On time operations
Delays
Turn-around time
Amount of vessels handled
Incidents
Near misses
Asset utilization
Added value to port
CAPEX
OPEX
Reliable
User-friendliness
Data availability
Flexibility

5.3.1. Categorisation

Collecting the weights will be done with the BWM method of Rezaei, 2015 in the next chapter. One requirement is that a set of attributes may not exceed 9 attributes. Thus the 17 relevant attributes must be divided into categories. Most studies on BWM divide attributes into two hierarchical levels. The aggregated categories from table 5.3 cannot be used as these are not on an equal hierarchical level. Operational efficiency is not on the same level as time-related processes and asset efficiency. These two attributes both explain operational efficiency. The categories should be chosen such that the performance attributes can be explained by the category. There are many ways of grouping attributes but there is no one right way. The grouping is designed through logic by the author and validated by experts. A grouping through applying a TEO framework has also been tested. It can be concluded that the framework does not lead to a suitable grouping and thus the grouping is done through the logic of the author.

A total of 17 mentioned attributes have been chosen from the mentioned attributes interviewed stakeholders. The attributes are chosen such that they can explain the performance of the innovation for all stakeholders. When grouping the attributes the question: 'what effect does the attribute have?' is asked for grouping the performance attributes. The performance attributes lead to three general effects:

commercial effects, operational effects, and safety effects. These three effects have been chosen as they are mentioned groups by the interviewed stakeholders. The 17 performance attributes will be divided into these three effects in the following manner (table 5.5):

Table 5.5: Performance attributes for evaluating innovations in port call management

Main category	**Attributes**	**Explanation**
Commercial effects	OPEX	Total operational costs for performing the entire port call. Typically costs consists out of personnel costs and costs for running assets.
	CAPEX	Total investment costs of the innovation (costs of new asset or building digital solution).
	Added value to port call	A value the innovation brings to the port call process chain. Value can be measured in euros or other units like time. This means the innovation brings more value to the entire chain than that it costs.
	Number of port calls	Total throughput for the entire port. Also referred to as the port's capacity.
Operational effects	Delays	Time difference between ETA and ATA.
	On time processes	The planned time of an activity in the port call process is actually met.
	Turn-around time	The total time between a vessel anchoring and leaving the port again.
	Environmental effect	Total CO2 emitted during a port call.
	Asset Utilisation	The rate resources of the port call process are used (tugs, cranes, pilotage boats etc.).
	Flexibility	The average time for last minute operations. The port call chain is able to respond well to last minute changes.
	(Data) Availability	Percentage of impacted stakeholders. The innovation can be available for all involved stakeholders. In case of data, the necessary data is transparent and available between stakeholders.
	(Data) Reliability	Percentage of down time. The innovation is mature and reliable for the users. In case of data, the shared data is correct and timely shared.
	User-friendliness	The system has a low complexity and is compatible with current procedures in the port call process. The innovation is easy to use and understand.
Safety effects	Incidents	The total amount of incidents during the port call operations.
	Near miss reports	The amount of near miss reports. These are situations which could have led to an incident or damage to an asset.
	(Cyber) Security	Security of data or assets against cyber attacks.
	Robust	The innovation is resilient to multiple user cases and is prone to errors. Amount of adverse conditions it withstands. For example: Rough weather.

The main category: commercial effects had 4 attributes. The OPEX and CAPEX are typically cost-related attributes. The added value and number of port calls are attributes related to the benefits the innovation brings.

The main category operational effects are all attributes that are important for the operations departments of the stakeholders. There are 3 sub-attributes related to time efficiency. One attribute concerns the environmental impact of an innovation. One attribute is the way assets are used. 4 attributes are about system requirements. One could argue to separate this category. However, system requirements are not on the same hierarchical level as commercial and safety. It can be argued that system attributes determine the operational effect of an innovation.

The main category safety effects hold 4 attributes that can describe the safety effects of an innovation. Safety is an attribute mentioned by almost all stakeholders during interviews. Besides running the port call process efficiently, safety is also an important factor.

Correlation
several attributes share correlation. Meaning that one attribute can be dependent on the other. For example, the turn-around time, delays, and on time processes influence the number of port calls. Also, asset utilisation has a strong dependency on added value. When assets like tugs are utilised more efficiently, the added value to the tug operator increases. The correlation is especially shared between commercial and operational attributes.

5.3.2. TOE Framework

The TOE framework of Tornatzky and Fleischer in 1990 is a well-used framework for classifying and ordering relevant factors for decision-making. The TOE framework is a good starting point for analysing the adoption of IT innovations at firm level (Chau and Tam, 1997; Praditya et al., 2017). The TOE framework makes the distinction of three aspects: Technology, Organisation, and External task Environment. The technology factor relates to the characteristics of the technology or innovation itself. The organisational factor relates to organisational processes. For example, the availability of resources, processes, size, and capabilities. The external task environment refers to factors related to the environment in which stakeholders are, the ecosystem, and its stakeholders.

This TOE framework has been applied to the identified performance attributes from the literature and the interviews. The applied framework can be found in Appendix D. A few problems arise when applying the framework. First of all, the technology exceeds the BWM maximum of 9 attributes and the external task environment category lacks with only 2 attributes. The second problem is that the TOE is a framework designed for adopting IT innovations. This doesn't fit the goals of this research as this research goes beyond the exploration of IT solutions. A port call innovation can also be a physical or organisational innovation. Because of these short comings, a TOE framework is not applied. The performance attributes have been established in the next section.

6

Relative importance of performance attributes

The results of the relative importance of attributes are presented in this chapter. The first section describes the respondents. Then the results of the weights are presented in 3 ways. First the overall results, where all the involved stakeholders are combined. Second, the weights per port are analysed. Thirdly, the weights per stakeholder group and individual results are discussed. The last section will conclude and provide answer to sub-questions 2 and 3.

6.1 BWM respondents

To obtain the relative importance of attributes a preference statement survey has been sent out to all the port call stakeholders. The preference survey is a BWM survey where stakeholders were asked to give their best and worst attributes and compare other attributes to their best and worst. An example of this survey can be found in appendix E. One survey has been created for all the stakeholders and all the ports. The survey is kept the same for all ports in order to compare the results of the BWM. The survey has been sent out to all the stakeholders that were contacted when the decision attributes were gathered, these were 23 contacts. The perspective of a shipping company has been added. The respondents with corresponding backgrounds has been displayed in table 6.1. All contacts where asked to further distribute the survey to increase the responses. Unfortunately this was more difficult than expected as the total responses were 12 It can also be argued that respondents whom were not interviewed aren't able to fill in the survey very well. As they don't have the same background knowledge of the topic. The response rates are displayed in table 6.2. The sample size from each port is smaller than anticipated. It was preferred to have at least one respondent of each port call in every port, meaning you would have about 5 or 6 respondents per port. It was difficult to get in touch with the port call stakeholders of which KOTUG didn't have direct contact with. Respondents possibly felt less responsible for participating with a research if they were contacted indirectly.

Table 6.1: Overview Respondents BWM Survey

No.	Stakeholder	Title	Port
1	Port Authority	Group Harbour master	RAK Ports
2	Port Authority	Port Manager	RAK Ports
3	Port Authority	Port Development	Port Antwerp-Bruges
4	Port Authority	Harbour Master	Port of Sydney
5	Port Authority	Port Call Optimisation and Invoicing Manager	Port Tanger-Med
6	Tug Operator	General Manager	Port Antwerp-Bruges
7	Tug Operator	Commercial Manager	Port of Port Arthur
8	Tug Operator	Director of Operations	Port of Port Arthur
9	Tug Operator	Commercial Manager	Port of Sydney
10	Pilot Organisation	Operational Manager	Port of Port Arthur
11	Terminal	Operational Manager	Port Antwerp-Bruges
12	Shipping Company	Port Optimisation Manager	-

Table 6.2: Response rate overview

Group	Invitations	Respondents	Response rate
RAK Ports	3	2	67%
Port of Hamburg	3	0	0%
Port Antwerp-Bruges	7	3	43%
Port of Port Arthur	3	3	100%
Port of Sydney	3	2	67%
Port Tanger-Med	1	1	100%
Other	3	2	67%
Total	23	12	52%

Due to the lower response rate it is not possible to compare all the ports with each other. In Port of Hamburg it wasn't possible to get respondents for the BWM. For this reason the preferences of this port cannot be compared to other ports. The amount of respondents per port also varies, 2 ports with 3 respondents, 2 ports with 2 respondents, and 1 port with 1 respondent. The ports are also not represented by the same stakeholders seen in table 6.1. For this reason not all the ports can be compared with other. Ports with similar stakeholders can be compared.

6.2 Weights of attributes on macro level

This section presents the results of the BWM survey from all respondents. This is thus all the decision makers from all four ports with all different backgrounds. The Bayesian BWM is used to calculate the weights, as this is a good tool to calculate the weights for a group. Never the less, all the individual weights have also been calculated individually to check the consistency. It can be concluded that all stakeholders have filled in the BWM survey in a consistent manner. The highest consistency ratio was 0.26, a ratio close to 0 is most consistent Rezaei, 2015.

For calculating the weights below, the Bayesian BWM is used to first calculate the local weights of the main categories (Commercial effects, Operational effects, and Safety effects). The local weights are the 'inner' categorical weights. The local weights are also calculated for each sub-attributes. Then the global weights can be calculated by multiplying the local weights of the main attributes and each matching sub attributes. The global weights represents the relative importance of the attributes. The outcomes of these calculations can be found in appendix E.

When looking at the local weights of the main categories (figure 6.1), it can be seen that *Safety* (0.427) is valued as most important main attributes. *Operational* attributes (0.369) is valued as second most important attributes. This is quite a logical outcome as the objective of the port call process is to safely manoeuvre the vessels through the port. Some respondents indicated that operational attributes have a dependency on commercial attributes. Thus, if you have efficient operations it will lead to commercial interests. The Credal ranking, in figure 6.2, shows the confidence relations between the categories. It can be said with almost full confidence (87%) that Safety effects is more important than operational effects and 100% confidence over commercial effects. Also operational effects is with 97% confidence more important over commercial.

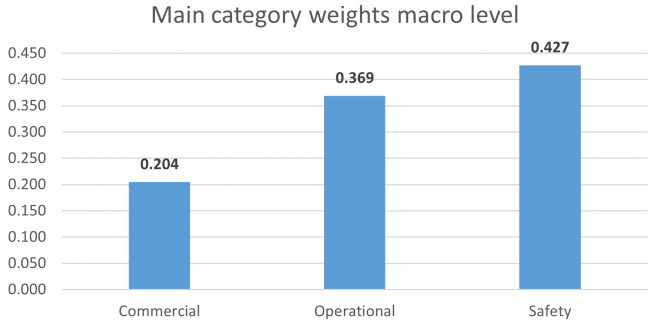


Figure 6.1: Weights of main categories on macro level

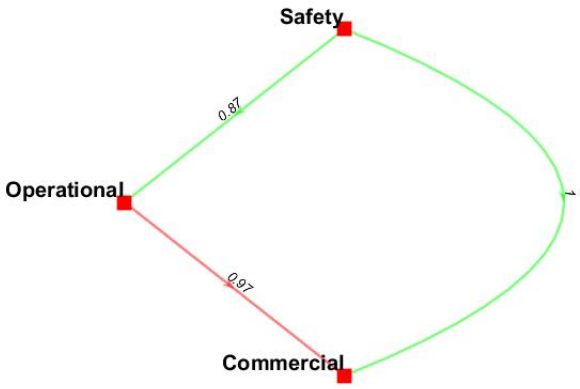


Figure 6.2: Credal ranking for main attributes of all respondents

When looking at the global weights of each sub attributes, it can be seen that *incidents* (0.144) is most important (figure 6.1). All factors from the safety category score relatively high due to the high main attributes score. The second most important scored attributes is *Robustness* (0.102), which means the innovation must work well and be resistance against errors. The third attribute is *near miss reports* (0.100). One respondent indicated near miss reports to be underrated and very important to learn from. The fourth most important attribute is *added value* (0.089), which is an attributes from the commercial category. Added value to the port call is relatively important to all the respondents. It is interesting as it is an attribute that indicates the benefits of a port call innovations on system level. However also logical as most stakeholders are commercially driven and want the benefits to be higher than the costs. It would not make sense to invest in an innovation that does not add value.

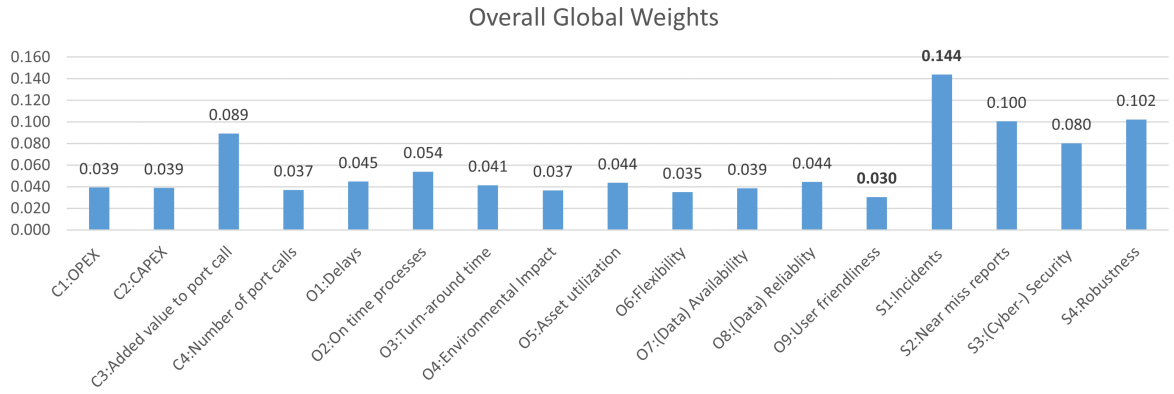


Figure 6.3: Global weights of attributes represented by all respondents

Local weights within categories

When looking at the local weights within the commercial category (figure 6.4), the added value to port calls (0.437) is the most preferred criterion within the commercial category. This means the net value an innovation brings to the port call process chain is generally seen as most important to all included stakeholders. Figure 6.5, shows that with 100% confidence added value is superior to the other attributes. The second and third most important attributes is OPEX (0.192) and CAPEX (0.190). The confidence relation between these attributes is 52%, thus it cannot be said that OPEX is superior to CAPEX. That leaves Number of port calls as least important attributes (0.181). The credal relations show that both OPEX and CAPEX are not superior over number of port calls. It can be said that the

number of port calls is generally least important to the stakeholders. This is a little surprising as the number of port calls in a port can relate to more revenue for all stakeholders. On the other hand, the objectives of port call stakeholders is not to increase or decrease the number of vessels but to make the process of a port call more efficient. More port calls could also have some side effects like more peak congestion.

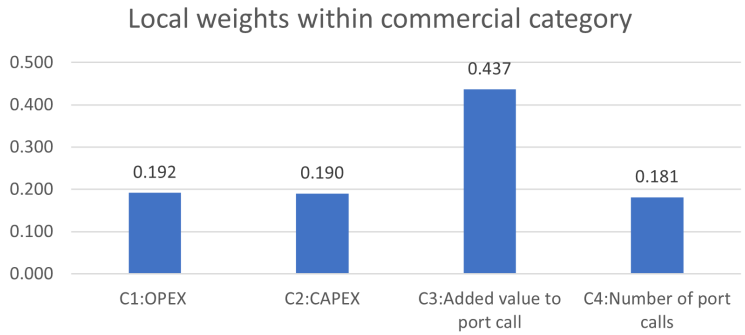


Figure 6.4: Local weights of attributes within commercial category

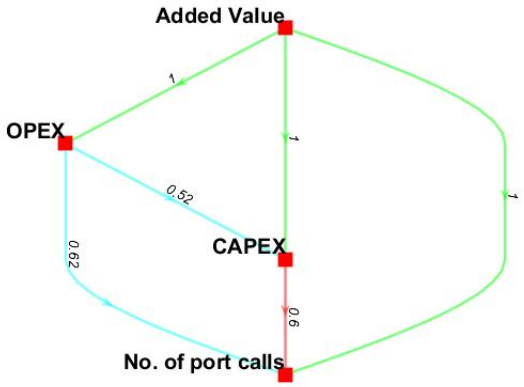


Figure 6.5: Credal ranking for sub attributes within commercial of all respondents

When looking at the local weights within operational attributes (figure 6.6), *on time processes* is most important (0.147). This is in line with the expectations as many stakeholders indicated during their interviews that as long as all processes happen on time there is no problem during a port call process. Port call optimisation can be argued, making sure all processes happen on time. *Delays* and *(Data) Reliability* both follow with close to equal importance (0.121 and 0.120 respectively). When deciding on a port call innovations it is important that it helps processes being on time, without delays and with operational reliability. If it is not a reliable innovation it does not make sense to implement.

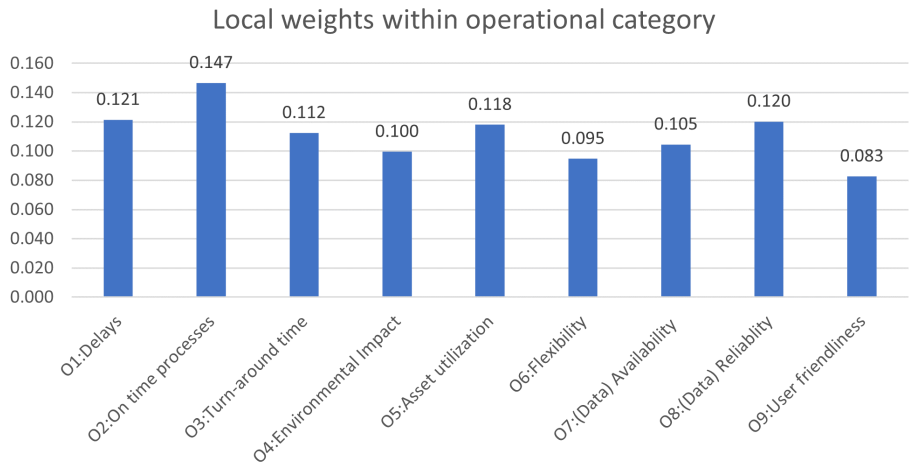


Figure 6.6: Local weights of attributes within operational category

The operational related attributes are weighted fairly equally 6.6. This can be seen in the lower credal ranking ratios between attributes. The credal rankings of the more important attributes are superior to the lower scoring attributes. However, attributes on similar level of importance do not have superiority over each other, as the credal ranking is closer to 0.5 (figure 6.7). The least important weight is user-friendliness (0.083). This is surprising because if an innovation is difficult to use then it may not be used at all. On the other hand, systems can be thought to be used. Stakeholders from these ports may not see this as a problem. Generally it can be concluded that the superiority between operational attributes cannot all be guaranteed. There is some more variation in the weighting of operational attributes between all stakeholders.

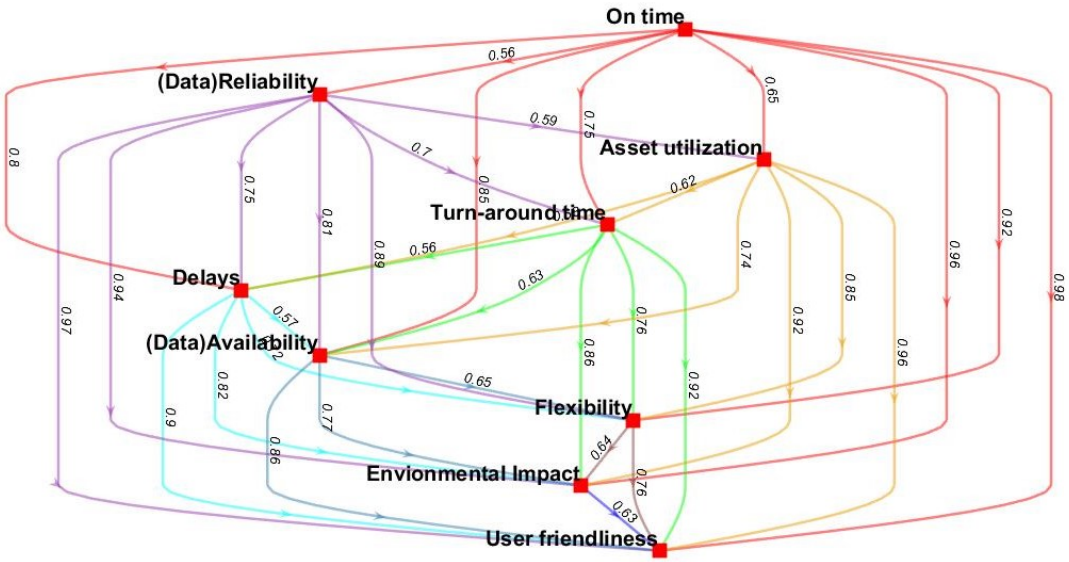


Figure 6.7: Credal ranking for sub attributes within operational of all respondents

When looking at local weights within Safety (figure 6.8), incidents is the most important attribute (0.337). This is means when deciding on a system or innovation it should not lead to more incidents during a port call. It is superior to near miss and (cyber-)security with 96% confidence and to robustness it is with 95% confidence superior (figure 6.9). (Cyber-)Security is generally seen as least important attribute. This is logical as there is currently not a lot of fear for security around nautical services. If the maritime industry gets targeted by cyber attacks more often it will become a more important attributes. Stakeholders are disagree about the importance of robustness and near miss reports. This confidence relation is 0.54.

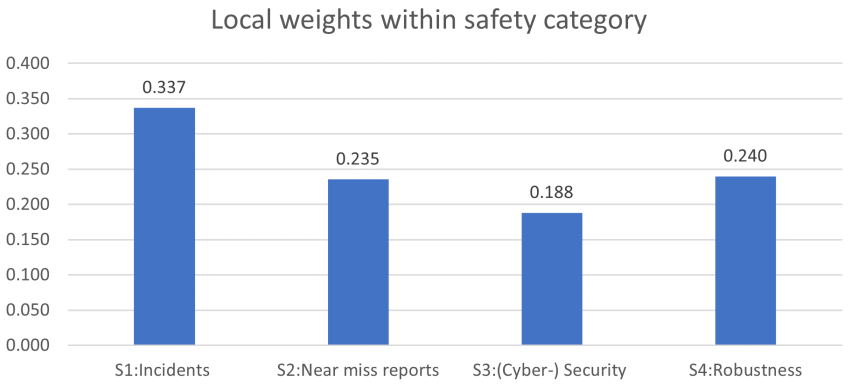


Figure 6.8: Local weights of attributes within safety category

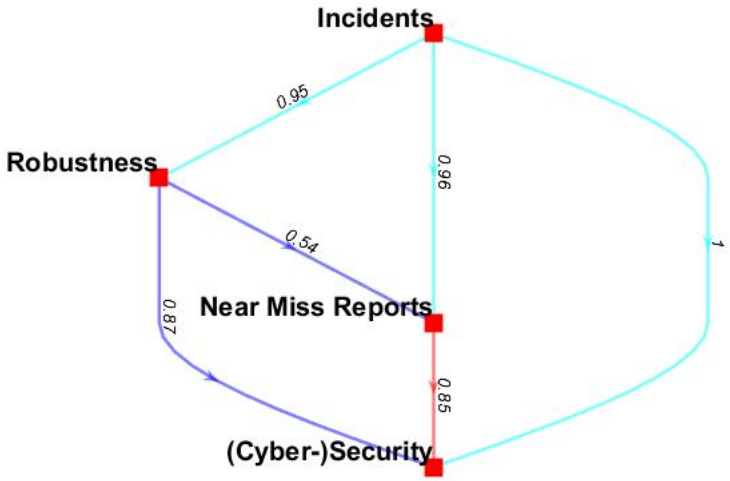


Figure 6.9: Credal ranking for sub attributes within safety of all respondents

6.3 Weights of attributes on micro level

The weights studied on micro level will take a closer look at the individual responses. This can give more detailed insights into how stakeholders weight performance attributes for port call innovations. First the weights between stakeholder groups are analysed. Thereafter the weights of the PAs from the different ports will be analysed. For each analysis the weights of the main categories are displayed and the global weights of all performance attributes. Local weights within each category can be found in appendix E.

6.3.1. Weights per stakeholder group

Figure 6.10, presents the global weights of the categories per stakeholder group.

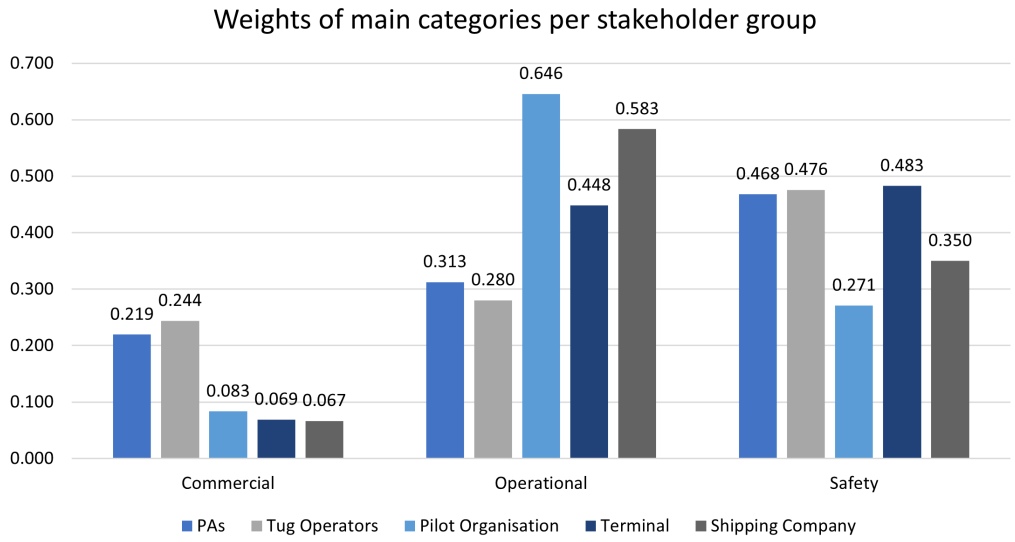


Figure 6.10: Weights of attributes form each stakeholder group

When comparing the weights per stakeholder group, the PAs and Tug operators score attributes very similar to each other. They both weight the safety attributes as most important (0.468 and 0.476) and commercial as least important (0.219 and 0.244). It would be expected that PAs score attributes on system level (and port related) relatively higher than tug operators. These results are slightly unexpected as the PA and tugs have different roles and responsibilities in the port. It was expected that tug operators might score commercial and operational attributes relatively higher as they are in a more competitive environment than PAs. This is not the case for these groups. The operational criteria for PAs are relatively important to the PAs. This will be further analysed by looking at the individual responses in the next section.

For the other stakeholders the results cannot be generalised over a group. Only one single respondent from a pilot organisation, terminal, and shipping company has filled in the BWM survey. However, it is interesting to see how these stakeholders weighted the performance attributes. From the weights of the main categories it is notable that the pilot, terminal, and shipping company weight commercial effects very low. Furthermore, the pilot organisation weights operational effect (0.646) very high compared to others.

Furthermore the global weights are studied in figure 6.11. Overall it can be seen that the stakeholders weight the performance attributes very diversely. With exception of the PAs and Tugs, as mentioned before. A few notable results can be seen:

First of all, there is a big difference in how near miss reports are weighted. The pilot organisation weight it very low and the terminal and shipping company both weight near miss reports are most important out of all performance attributes.

Secondly, the attributes *delays* and *asset utilization* are weighted relatively important by only the pilot organisation. Meaning the pilots are utilised efficiently. This is understandable as pilots are an expensive nautical service provider.

Thirdly, an interesting result is that the shipping company is the only stakeholder that scores *Environmental impact* relatively high compared to all other stakeholders. The shipping company has a global perspective on port calls, not biased by a specific port. The other port call stakeholders have mentioned environmental impact not to be as important at this moment. Improving operations will automatically lead to environmental impact. It may be not as important for nautical service providers because their environmental impact is much smaller compared to the larger vessels of shipping companies.

Lastly, attributes directly impacting the incoming or outgoing vessel is weighted relatively important by pilots, terminals and shipping companies. Such attributes are: *On time processes, Turn-around time, asset utilization, reliability etc.*

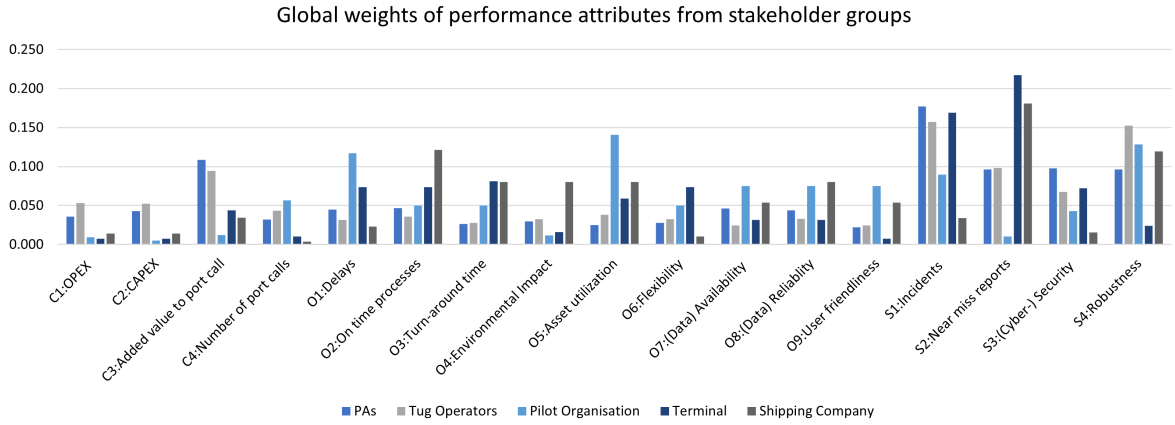
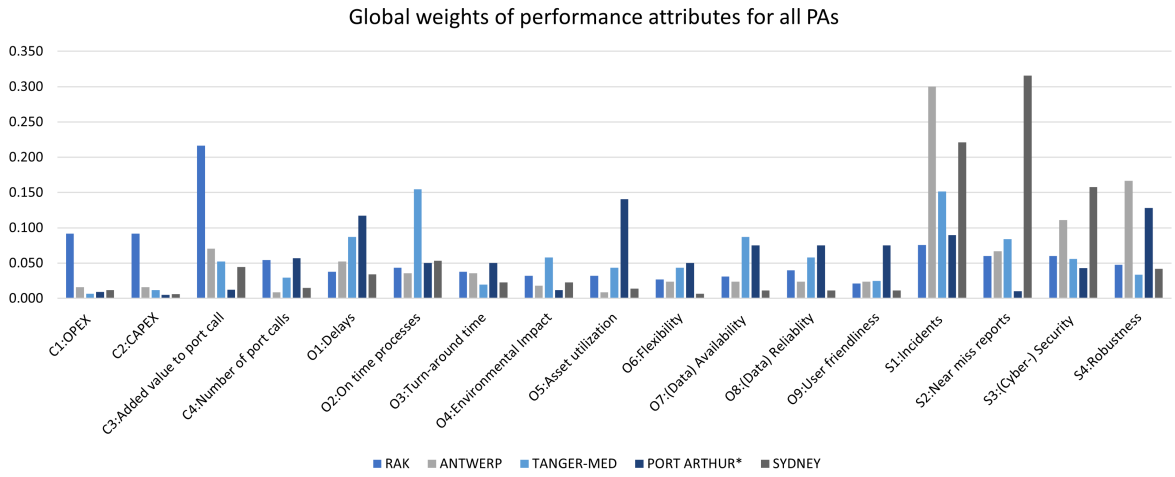


Figure 6.11: Global Weights of attributes of stakeholder groups

6.3.2. Weights from individual stakeholders

Weights from all Port Authorities

This section analyses the BWM responses of the individual PAs and the individual tug operators. The individual responses from the PAs, figure 6.12, has been filled in diversely. Each PA respondent had a different best and worst attribute. One trend is very clear, the commercial attributes is only scored as important by the PA of RAK Ports. The other ports score this attributes relatively low. This may become logical when looking at the port context of RAK Ports. The other PAs in ports (Antwerp-Bruges, Tanger-Med, and Port Arthur) with a decentralised management structure, weight commercial attributes lower than a port which is centralised and has a service management model. These PAs value safety or operational attributes as more important. The PAs of Port of Sydney, Antwerp, and Port of Port Arthur weight safety attributes as relatively more important.



* Port of Port Arthur doesn't have a PA. The pilots control the VTS and act like the PA during a port call

Figure 6.12: Global Weights of attributes from all Port Authorities

Weights from all tug operators

When comparing the individual results of the tug operators with each other, it is more difficult to find clear trends (6.13). One noticeable difference is that tugs from Port of Sydney score *added value* (0.442) much more important than tugs from port Antwerp-Bruges and Port Arthur. The main difference for tugs is that in port Antwerp and Port Arthur the nautical restrictions are rather complex thus relatively higher importance for safety attributes is logical. Port of Sydney has simple nautical restrictions and can thus explain the lower score on safety attributes. Operational attributes are scored relatively low.

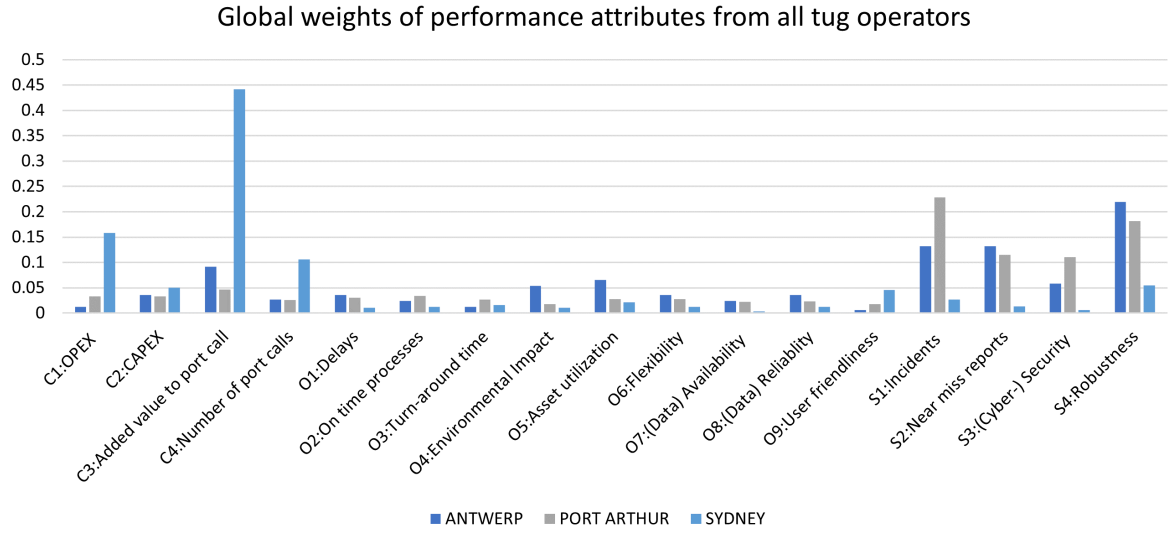


Figure 6.13: Global Weights of attributes from all Tug Operator

6.4 Conclusion

This chapter answers the sub-questions 2 and 3 of this thesis:

SQ2. How are the proposed performance attributes weighted by the stakeholders?

SQ3. How can heterogeneity and homogeneity in weights be explained by the port cases?

The weights of the attributes have been collected with the BWM survey and analysed on a macro-level and micro-level. The macro-level is all respondents which is a representation of the port call industry on an individual stakeholder level. The results on the macro-level are calculated with the Bayesian BWM and on micro-level with the regular BWM. Both analyses provide useful insights.

The results on the macro-level lead to the following preference order (from most important to least): Safety, Operational, Commercial. Overall the safety attributes are scored as most important according to all the involved stakeholders. Compared to the most mentioned attributes from interviews, it was not in line with expectations. The most mentioned attributes were more operational-related attributes. Thus the safety effects of an innovation in port call management are the most important. When taking a closer look at the global weights, the top 4 performance attributes are: incidents (0.144), robustness (0.102), near-miss reports (0.100), added value (0.089). This means when deciding on port call innovations, the score on the safety aspect is important and it must add value to the port. Thus, it can be concluded that a port call innovation should most importantly be safe and add value to the port call process. Meaning having more benefits than costs for each stakeholder. This is logical because most respondents are commercially driven or want to add value to the port. The least important attributes are: User-friendliness (0.030), flexibility (0.035), and environmental impact (0.037). User-friendliness is slightly surprising. Flexibility and environmental impact is more logical. Within port call management it is not desired to have last-minute changes in the planning. This leads to complexity. The innovation does not have to perform well on flexibility. At this moment the port call stakeholders weigh environmental impact as not very important in port call management. It is expected that this will change in the future.

In the second analysis, the weights have been analysed on micro-level. The weights have been analysed per stakeholder group and individual. First, the group of stakeholders are compared. The port authorities and tug operators are represented by 4 stakeholders each. The results show that the aggregated weights of these stakeholders are very similar, with safety (0.468 and 0.476 respectively) as the most important attribute and commercial (0.219 and 0.244) as the worst (see figure 6.10). For PAs this is a logical preference as their task is to supervise safety during a port call. For tug operators it is a slightly more surprising outcome. The non-aggregated results will be interesting to study. Three conclusions from studying the global weights of the stakeholder groups are noted:

First of all, the difference in how stakeholders weigh near-miss reports. The pilot weighted it very low and the terminal and shipping both as the most important performance attribute. Secondly, *delays* and *asset utilization* are weighted relatively important by only the pilot organisation. Meaning the pilot is looking for innovations that utilise assets efficiently. This is understandable as pilots are expensive nautical service providers. Thirdly, the shipping company is the only stakeholder that weighs environmental impact relatively higher compared to others.

When looking at the scoring of the attributes within ports, it can be concluded that RAK Ports, and Port Antwerp-Bruges scored the attributes relatively similarly. These analyses can be found in appendix E. Not a big conflict in performance attributes in these ports towards port call innovations. In Port of Sydney and port of Port Arthur, the stakeholders valued the attributes very differently. Here there is a conflict in interests.

In the last analysis, the weights per stakeholder of the PAs and tug operators are analysed. This can be understood by looking at the individual weights. Looking at the non-aggregated individual weights of the PAs, each PA has different best and worst attributes. Thus the PA weighs the attributes very differently from each other (see figure 6.12). This is because each port is different and the role of

the PA varies. One trend is clear, and that is how port authorities score commercial attributes. It can be concluded that the PAs in ports with a decentralised management structure weigh commercial attributes lower than a port that is centralised and has a service management model. Furthermore, the non-aggregated weights of each tug operator show that the tug operator in Sydney scores opposite importance (with commercial as most important) compared to the tug operators from Antwerp-Bruges and Port Arthur. In Sydney the tugs are licensed and in the Antwerp-Bruges and Port Arthur they are not. This is not expected because tugs in a non-licensed environment would experience more competition. This outcome could be due to the interpretation of the survey.

To conclude, there is generally quite a lot of heterogeneity in the weights of performance attributes for port call innovations. When analysing the results some heterogeneity and homogeneity in weights can be explained by the port contexts. Two clear trends have been identified. One clear trend is that the RAK Ports, with a centralised service management PA, score commercial attributes relatively higher than the other ports with a decentralised landlord management. Another logical homogeneity is found in ports Antwerp-Bruges and Port of Port Arthur. Due to the complex nautical restricted ports, they score safety relatively higher. Furthermore, homogeneity has been found within the ports of RAK Ports, Port Antwerp-Bruges, and port of Port Arthur. Thus there is less conflict in performance attributes between stakeholders for evaluating port call innovations. In Port of Sydney, there is large heterogeneity in the weights of performance attributes.

7

Conclusion and Discussion

First the conclusion of this thesis is presented. The answers to the sub-questions and the main research questions will be handled here. Then after, the expectations and relevance of this thesis is discussed. Then the limitations and reflections of the research is discussed. At last further research is advised.

7.1 Conclusion

This thesis was conducted to fill the gap of performance attributes for evaluating innovations in port call management. Optimising a port call process is a motive to increase the performance of a port and contribute to maritime challenges. Improving the port call process can be facilitated through several innovations that improve collaboration, increase capacity, or utilises assets more efficiently. An innovation can be anything from a tool, asset, or strategy to improve the port call. The best innovation depends on the performance attributes identified and the preferences of the stakeholders. From the ports, there is a need to optimise the port call. However, as far as the author is aware, the performance attributes and their weights have not been addressed by literature before. For this reason, the main objective of this thesis was: to identify the relative importance of performance attributes for innovations in port call management. The relative importance of performance attributes is determined by the stakeholders involved in the port call process. A port call is a complex process, with many different involved stakeholders with various interests. The process of port call differs from port to port based on specific rules or ways of working. Thus heterogeneity is expected in the relative importance of the stakeholders. Six various ports have been studied to identify and understand differences and similarities in objectives and preferences. To achieve this goal, the following research question and sub-questions have been answered:

Before answering the main research question, the sub-questions are answered below:

1. *What are relevant performance attributes for evaluating innovations in port call management?*

This sub-question was answered in chapter 5 by performing semi-structured interviews. Literature related to port calls and other shipping studies has identified a gap in literature concerning performance attributes for port call management. During 14 interviews, 65 attributes have been mentioned. In total 17 performance attributes have been selected as relevant for evaluating innovations in port call management. For the BWM method, the attributes are classified into three main categories: commercial effects, operational effects, and safety effects. The categories have been made according to the main effect a performance attribute has on port call management. There is some correlation between attributes. Furthermore, the performance attributes have been designed, where all attributes are interpretable on the system level. This means the performance attributes are not stakeholder or port-specific. From the interviews the most mentioned attributes were related to time, operational efficiency, and safety.

The performance attributes are distributed in the following manner. Within the commercial category, there are two attributes related to the costs of an innovation: OPEX and CAPEX. Operational costs are variable costs and capital costs which are one time expenditures. The attribute: Added value to the port call, represents the benefit of an innovation. The number of port calls can be important as it refers to revenue for some stakeholders.

Secondly, the operational category is the largest with nine attributes. Three are related to time: Delays, On time processes, and turn-around time. Asset utilization is mentioned to be important by one study Lokin, 2022. Other attributes are more requirements/characteristics of the innovation: Flexibility, Availability, Reliability, and User-friendliness. Environmental Impact has not been mentioned often but it is an increasing topic in the maritime.

Thirdly, safety effects are represented by incidents and near misses. An innovation could be promising but safety during a port call should be guaranteed. It is the third most mentioned attribute from interviews. (Cyber-) Security and robustness of the innovation are also classified as safety attributes. Not mentioned as much but could be very relevant for some more advanced innovations.

2. How are the proposed performance attributes weighted by the stakeholders?
This sub-question was answered in chapter 6 using the best worst method to indicate the relative importance of the proposed attributes. The proposed attributes have been weighted by 12 stakeholders from 6 ports with various backgrounds. On the macro-level, it can be concluded that safety effects are considered as most important attribute followed by operational effects. This is slightly unexpected as these do not correlate with the most mentioned attribute from the interviews. When taking a closer look at the preferred performance attributes, the top 4 most important attributes are: incidents (0.144), robustness (0.102), near-miss reports (0.100), added value (0.089). The 3 least important attributes are: User-friendliness (0.030), flexibility (0.035), and environmental impact (0.037). Overall, it can be concluded that according to the stakeholders, an innovation must perform well on the safety aspect and add value to the port call process. At this moment it is less important how the innovations perform on user-friendliness, flexibility, and environmental impact.

Furthermore, the weights of the attributes are analysed on the micro-level. First of all the results from different stakeholder groups show that there is homogeneity in the weights of the PA and tug operators, with safety (0.468 and 0.476 respectively) as the most important attribute and commercial (0.219 and 0.244) as the worst. This is a logical outcome for the PA as the majority of the PAs have the task to guarantee safety during a port call and not interfere with planning or commercial interests. For the tug operators it is slightly surprising. One would expect them to score commercial and operational attributes relatively more important seen that the responded operators work in a more competitive market (tug operators are not always in a competitive market). Lastly, the shipping company and terminal weighted operational attributes related to time relatively higher than others. This could be because they are most impacted if the port call does not run on time. Other than that the stakeholder groups weigh performance attributes differently from each other. Generally, there is heterogeneity in the weights of performance attributes.

Secondly, the weights per stakeholder of the PAs and tug operators have been analysed. The individual responses have been laid side by side. Between the PAs there is heterogeneity in the weights of the performance attributes. This is an expected result because all the ports operate differently. Heterogeneity could be explained by the differences in port contexts. The tug operators generally show more homogeneity with relatively high importance for safety attributes. Except for the tug operator in Port of Sydney, which scores commercial attributes relatively higher.

When looking at the scoring of attributes within ports, it can be concluded that the respondents from RAK Ports and Port Antwerp-Bruges, scored the attributes relatively similarly. There is not a big conflict in interests in these ports towards port call innovations. In Port of Sydney and port of Port Arthur the stakeholders valued the attributes differently. Here there is more diversity in preferences for evaluating port call innovations.

3. How can heterogeneity and homogeneity in weights be explained by the port cases?
The answer to this sub-question can also be found in chapter 6. Some of the given weights can be explained by the port's case but others are more difficult to explain. The first observation is that the stakeholders in port Antwerp-Bruges and port of Port Arthur score very similar with safety effects as the most important attributes and commercial effects as the least important. These ports both have complex nautical restrictions and are decentralised. The complex nautical restrictions could explain

the high safety preference. The other ports are nautically simpler and score relatively lower on safety. A second observation is that RAK Ports has a relatively high score for commercial attributes. Their main objective as a port is to stay cost competitive. The port has a centralised management structure and the PA has a service management role meaning the PA is the only operator in the port. This also explains the homogeneity of preferences of stakeholders within the RAK Ports. All departments work towards the same objective. The third observation is that the PA of port Tanger-Med scores operational attributes relatively higher than other ports. This could be explained because the port's objective is to be efficient. Tanger-Med is more performance-oriented than other ports which explain the preferences for operational attributes like delays and on-time processes. The PA follows a landlord model, however with its own pilots and all services licensed. The PA shows an involved role in the port call process. The preferences of the PA from Tanger-Med are quite similar to the preferences of the shipping companies. This could be because the shipping companies play a dominant role in this port by owning the terminals and having long-term contracts with tugs.

"How do stakeholders in different ports value performance attributes for evaluating innovations in port call management?"

All in all, this thesis finds that the relative importance of performance attributes for port call innovations varies between stakeholders of ports and in some cases within ports. Moreover, each port is unique and should be studied individually. Some differences and similarities in weights have been identified and could seem logical when looking at the port's context. Similarities have been found in stakeholders from two ports with complex nautical restrictions. They score safety attributes relatively higher than ports without complex nautical restrictions. More similarity is found in the preferences of stakeholders of a port with centralised and a service management model. These stakeholders are internally more aligned than other decentralised ports. Finally, the preferences of the PA are influenced by the involvement and objective of the PA in the port call process. The weights the PA gives to performance attributes can in some cases be explained by the port's context.

7.2 Expectations

The results of this thesis show similarities with findings from other studies. Several studies have pointed out that factors like PA strategy and port management model influence the collaboration within a port and thus the preference for port call innovations (Lind, Ward, and Bergmann, 2020; Imset, 2021). This can be confirmed by the difference in weights of ports of RAK Ports and Tanger-Med. Both with different strategies and port management models. The second finding is similar to that of Lokin, 2022's optimisation objectives. The shipping company values on-time processes and turn-around time relatively higher than other stakeholders. Pilots find asset utilization important. Pilots are expensive tasks and pilots have a maximum amount of hours they can work. Surprisingly the tug operators do not value asset utilization very highly. The terminal in this thesis values these attributes relatively high instead of berth utilization.

Overall the safety effect is valued as the most important category. This is not in line with expectations as operational attributes were more often mentioned. The identified factors in ports that are important for understanding the preferences are: Management model, nautical restrictions, role of the PA (licensed port), port competition. This is in line with the factors mentioned by World Bank, 2022. Poulsen and Sampson, 2020, study suggests that best practices might be present when the same company owns terminals and cargoes and/or ships and ensures port stakeholder coordination. This is true for Tanger-Med as these ports have less conflicting interests.

7.3 Academic Relevance

The topic of port call optimisation is understudied in literature with only 24 appearances on Scopus. Several studies have explored tools and concepts for port call optimisation, with promising proof of concepts. Still, port call optimisation is nascent in current literature. Multiple innovations or strategies can help improve problems in the port calls. 'What' performance attributes, for evaluating such innovations, and 'how' these are preferred by the stakeholders have never been studied before. This thesis contributes by identifying and understanding the relative importance of performance attributes for innovations in port call management. Researching preferences in multiple port cases could help understand why the ports have certain preferences. This is done by involving stakeholders from multiple ports. Studying multiple ports also contributes to the understanding of how port call processes are organised in various ports. Studying the port call processes in various ports is a research suggestion by Molkenboer, 2020.

The overall results of this thesis show that performance attributes with *safety* effects are the most preferred and *commercial* effects are the least important attributes for evaluating port call innovations. These preferences differ according to the port in which the innovation is being explored in. Exploring and understanding these preferences can lead to better innovation design for port call optimisation. In the end, this may lead to better fit innovations to the specific port. If the innovations are a better fit they are more likely to be implemented and address the maritime challenges; reducing peak congestion in ports and reducing GHG emissions. This thesis has found that the factors: management, role of PA, stakeholders, and nautical restrictions distinguish port call management. The difference of factors that explain how a port is organised has also never been done before. Except the world bank management tool.

7.4 Practical relevance

In terms of practical takeaways this thesis can help with better decision-making for port call innovations in certain ports. Moreover, it helps to understand why ports have certain preferences. Developers of tools or strategies for improving port call management may get a general idea of what design aspects to focus on in certain organised ports. The weights of the performance attributes indicate what attributes the stakeholders find relatively important. This gives an idea of what innovations developers can focus on. As concluded within this thesis there is quite some heterogeneity in preferences. Therefore the findings of this thesis advised studying each port individually. The analysis of this thesis does give a general idea about what performance attributes could be preferred in certain ports. Some examples are:

Ports with complex nautical restrictions and multiple industries prefer innovations that score well on safety and operations. Innovations like remote pilotage or tug operations will probably not be preferred in these ports. Innovations that allow for collaboration and transparency in vessel traffic management will probably be preferred in such ports.

Ports like Tanger-Med without complex restrictions, licensed activities, and single industry prefer innovations that score well on operational effects. Innovations that perform well on attributes like waiting time and delays will probably be preferred in such ports. Innovations like improved planning of resources could be an example of this.

Another practical learning that can be deduced from the results is that not all ports are eager to optimise the port call process. Some ports don't see the need to optimise their port call process. It is not always the main bottleneck of the port and some ports don't have much port competition. Thus, not having much incentive to optimise as a lower performance does not directly hurt the port. For example, at the port of Sydney the PA has already made efforts to run the port call efficiently. Its main focus now is on guaranteeing safe operations. Ports with more competitive surroundings like Port Antwerp-Bruges, Tanger-Med, and the port of Port Arthur are more eager to improve the port call process.

7.5 Relevance for KOTUG Optiport

KOTUG Optiport is an optimal scheduling tool for tug boats. With this tool tug boats are planned optimally to reduce costs. This tool can be seen as an innovation to improve the port call process. This tool currently optimises the schedule of tug boats. A long-term goal could be to extend the tool towards full port call optimisation where all nautical services are optimally scheduled in one tool. This thesis adds to this goal by researching what the different interests are in ports and understanding why these ports have these interests.

Logically ports with a more centralised management don't have conflicting interests and are more willing to collaborate internally. These ports however often operate efficiently and don't have the necessity to implement such a tool as there is no collaboration conflict. The entire organisation has one objective thus it is easier to optimise with one objective instead of many conflicting objectives. Ports that are more complex in terms of nautical restrictions, industries, or congestion have a higher need to plan and coordinate port calls efficiently. These ports prefer innovations that score well on operations. The cases reveal that the port of Tanger-Med and port of port Arthur resemble examples of the aforementioned. Such ports are keener to adopt an optimal scheduling tool than other ports.

Furthermore, a port like port Antwerp-Bruges and port of Port Arthur value safety as an important attribute. One could argue that Optiport offers more insights into the future of what is required in a port call. This way the nautical services are more aware of what is to come in the future. This could show a decrease in the number of near misses in a port. Similar results are seen from HVCC in Hamburg where they provide insights into the planning further ahead.

Optiport as a full port call optimisation tool may work in ports that are either centralised, with a full service model, and have complex nautical restrictions to plan assets more efficiently. This due to the non-conflicting interests in a port. Nautically complex ports with decentralised management and a landlord model, may have the urge to plan assets efficiently. In such ports, there are conflicting interests due to competitive markets. Ports which have licensed nautical services and where the PA plays a more active role during the port call could be more open or willing to implement such a tool than completely open landlord ports.

With this thesis KOTUG gets an idea about, on system level, the type of ports that are fit for port call optimisation with Optiport. In the future when Optiport is developed for optimally scheduling several nautical services KOTUG could use a BWM Survey to get an understanding of how their specific clients value optimisation objectives. This could then be used as input when making a multi-objective optimisation.

7.6 Limitations and reflection

All research methods have some limitations which can criticise the results found. It is good to discuss these limitations to guide further research. The BWM method has multiple limitations: Interpretations and biases, and temporal dimension. The results and research choices will also be reflected on sample size, validity, categorisation of attributes, and case studies.

Limitation

Firstly, the limitations of the BWM method. The interpretation and biases of the attributes can vary per stakeholder and affect how the BWM survey is filled in. The background and stakeholder's role can affect the results. An effort is made to provide clear and non-steering definitions, however interpretation and biases can still affect the results. Feedback from the BWM survey revealed difficulty in making considerations between attributes. This could be because of the definitions or categorisation of the attributes. The BWM results have a temporal dimension meaning the results are time-related. It could be that the preferences of the stakeholders change in the future when new problems arise in ports. Despite these limitations of the method, the BWM is still a strong and consistent methodology to identify the relative importance of certain criteria (i.e., attributes).

Reflection

Secondly, reflecting the results of this thesis. The number of respondents for the BWM was much lower than anticipated. KOTUG provided good initial contacts. However, it was challenging to get in contact with other stakeholders. The goal was to get 5 to 6 respondents per port but only 1 to 3 were eventually recorded. This limited the comparison possibilities of certain ports because the sample size of the respondents was not the same. If this would have been known beforehand, my preference would have gone for fewer ports to ensure a greater response rate. Subsequently, this would have led to stronger micro-level analysis meaning the statistical validity of comparing preferences between and within ports could be improved. Then again, researching 6 ports does give a more global perspective on the macro-level. With more respondents, the superiority of one attribute over the other becomes more reliable.

Moreover, the selection and categorisation of attributes was quite challenging. Stakeholders gave many criteria and KPIs. It was quite challenging to organise these and make one set of attributes that is applicable to every stakeholder in all ports. The BWM does not account for correlation between attributes. However, some performance attributes do correlate in the proposed list. This is something that is recommended to be taken into consideration in the future when selecting attributes. The BWM method can only account for a maximum of 9 attributes. For this reason, it is very common to categorise the attributes in BWM literature. This can be done with the help of a framework. However, in this research applying the common TOE framework did not lead to suitable classification. The categorisation is made by the authors' common sense. This leads to discussions on what choices are made. For example, there is an unbalance in the size of the main categories of the attributes. Operational effects count 9 attributes whereas the others count 4. Because the weights add up to 1 the sub-attributes from operational attributes have relatively lower weights than the other categories. If this categorisation could be redone more categories would have been structured, as well as more expert consultation per category types.

7.7 Further Research

Further research could be done to address the limitations of this thesis. The study could include more respondents to make the results more valid and significant. This would allow for more extensive comparison between ports. The research could also be repeated for other ports with similar port contexts to add to the body of knowledge. And thus understand how port call stakeholders value performance attributes. Repeating the BWM in other ports could also further help in understanding why ports value certain attributes and give more insights into what factors in ports are relevant for optimising the port call process.

This thesis has identified the relative importance of performance attributes for port call innovations. The logical following step would be to design innovations for ports and assess these innovations in the specific port. An agent-based model or simulation model could be made to explore the performance and effects certain innovations could have for port call optimisation. These are good methodologies to measure the effects of interventions in simulated real-world scenarios. In pursuit of such an approach, it would be advised to focus on one specific case as each port system is different. This thesis can only speculate about the performance of innovations. The output of the simulation together with the found weights could then be used in determining the preferred innovations for a port.

The results of this thesis show that there is quite some heterogeneity in the preferences of stakeholders. During interviews, it also became evident that not all ports are in need for port call optimisation. Ports have different needs for port call optimisation. To add to the body of literature, quantitative research could be done in understanding how to reach port call optimisation in certain ports. As each port has unique preferences it is advised to study ports individually. And start with ports where the need for port call optimisation is relatively high and there is homogeneity in preferences. A study could be done in making a strategic road map towards port call optimisation for a specific port. Such a study would have to identify the needs and definition of port call optimisation for each stakeholder. Next strategies would be best to show how interventions could reach port call optimisation. Such a road map could be generalised for similar organised ports. This will help ports towards port call optimisation.

References

(2018). https://portcalloptimization.org/

Bond, S. D., Carlson, K. A., & Keeney, R. L. (2008). Generating objectives: Can decision makers articulate what they want? *Management Science*, *54*(1), 56–70.

Brand, L. (2022). Storing vital products with care - Vopak. *Smart Marit. Conf.* https://smartmaritimenetwork.com/wp-content/uploads/2022/05/Leo-Brand-CIO-Vopak-Digitalisation-as-a-Critical-Success-Factor-for-the-Future-of-Logistics-Chains.pdf

Broersma, C. F. (2021). *Abating GHG Emissions with Dynamic Arrival Times* (Doctoral dissertation). Delft University of Technology.

Browne, D., & Ryan, L. (2011). Comparative analysis of evaluation techniques for transport policies. *Environ. Impact Assess. Rev.*, *31*(3), 226–233. https://doi.org/10.1016/j.eiar.2010.11.001

Ceder, S., Gustafsson, N., Nilsson, H., Von Nordenskjöld, A., Stjernström, P., & Torbjörnsson, J. (2018). *Port Call Synchronization* (Doctoral dissertation). UNIVERSITY OF GOTHENBURG.

Chau, P. Y. K., & Tam, K. Y. (1997). Factors affecting the adoption of open systems: An exploratory study. *MIS Quarterly*, *21*(1), 1–24. Retrieved October 16, 2022, from http://www.jstor.org/stable/249740

Davydenko, I. Y., & Fransen, R. W. (2019). Conceptual Agent Based Model Simulation for the Port Nautical Services. *IFAC-PapersOnLine*, *52*(3), 19–24. https://doi.org/10.1016/J.IFACOL.2019.06.004

Fahim, P. B., Rezaei, J., Montreuil, B., & Tavasszy, L. (2022). Port performance evaluation and selection in the Physical Internet. *Transp. Policy*, *124*, 83–94. https://doi.org/10.1016/j.tranpol.2021.07.013

Foulquier, E., & Maugeri, S. (2012). The port as a territory: an exceptional space or a common good? Discussing deficiency in port governance. *Investig. y Desarro.*, *20*, 32–53.

Fransen, R., & Davydenko, I. (2021). Empirical agent-based model simulation for the port nautical services: A case study for the Port of Rotterdam. *Marit. Transp. Res.*, *2*. https://doi.org/10.1016/J.MARTRA.2021.100040

Gan, Z. (2019). *Simulating the Nautical Chain of Operations in the Deep-Sea Port* (Doctoral dissertation). Delft University of Technology. http://resolver.tudelft.nl/uuid:03ad40c4-bd5e-4b8a-a3b4-22b04e09a19f

HCVV. (2022). Retrieved June 23, 2022, from https://www.hvcc-hamburg.de/en/

IMO. (2018). Initial IMO GHG Strategy. Retrieved September 5, 2022, from https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx

IMO. (2020a). IMO and the Sustainable Development Goals | IMO. *IMO Sustain. Dev. goals*. https://www.imo.org/en/MediaCentre/HotTopics/Pages/SustainableDevelopmentGoals.aspx

IMO. (2020b). *Just In Time Arrival Guide - Barriers and Potential Solutions* (tech. rep.). https://wwwcdn.imo.org/localresources/en/OurWork/PartnershipsProjects/Documents/GIA-just-in-time-hires.pdf

IMO, & Roumelioti, N. (2022). *Just In Time Arrival - Emission reduction potential in global container shipping* (tech. rep.). IMO. https://greenvoyage2050.imo.org/wp-content/uploads/2022/06/JIT-Container-Study.pdf

Imset, M. (2021). Drivers and barriers for the involvement of port agents in digital transformation of port ecosystems Lizbeth Salas Nordli. *Reconnect, Rediscover, Reimagine*, (December).

Keeney, R. L. (1996). Value-focused thinking: Identifying decision opportunities and creating alternatives. *Eur. J. Oper. Res.*, *92*(3), 537–549. https://doi.org/10.1016/0377-2217(96)00004-5

Keeny, R. L. (1996). *Value-Focused Thinking*.

Lind, M., Becha, H., Simha, A., Erik Larsen, S., Ben-Amram, E., & Gnass, M. (2021). Port Call Optimization: Two Sides of the Same Coin. Retrieved April 25, 2022, from https://www.maritime-executive.com/editorials/port-call-optimization-two-sides-of-the-same-coin

Lind, M., Bergmann, M., Bjørn-andersen, N., Robert, W., Haraldson, S., Watson, R., Andersen, T., Michaelides, M., Evmides, N., Gerosavva, N., Karlsson, M., Holm, H., Olsson, E., Zerem, A., Herodotou, H., Ferrus, G., Gimenez, J., Arjona, J., Marquez, M., … Gonzales, A. (2019). Substantial value for shipping found in PortCDM testbeds by 30 th of March 2019. *2019*(March).

Lind, M., Bergmann, M., Haraldson, S., Watson, R. T., Park, J., Gimenez, J., & Andersen, T. (2018). Port Collaborative Decision Making (PortCDM): An enabler for Port Call Optimization empowered by international harmonization. (January).

Lind, M., Haraldson, S., Karlsson, M., & Watson, R. T. (2016). Overcoming the inability to predict-a PortCDM future. *10th IHMA Congr. Port Mar. Oper. Vancouver, Canada*.

Lind, M., Haraldson, S., Karlsson, M., & Watson, R. T. (2015). Port Collaborative Decision Making – Closing the Loop in Sea Traffic Management. *14th Int. Conf. Comput. Appl. Inf. Technol. Marit. Ind.*, (2009), 499–515. http://monalisaproject.eu/wp-content/uploads/Compit-2015-Port-CDM-Lind.pdf%7B%5C%%7D0Ahttps://pdfs.semanticscholar.org/ce1b/4e555d67e957e407944c6fbb7e69c6c4f5bb.pdf

Lind, M., Ward, R., & Bergmann, M. (2020). *Digitalizing the port call process*. https://doi.org/10.13140/RG.2.2.33562.26568

Lind, M., Ward, R., Bergmann, M., Haraldson, S., Zerem, A., & Hoffmann, J. (2020). *Digitalizing the port call process*. https://doi.org/10.13140/RG.2.2.33562.26568

Lokin, J. W. (2022). *Integration of port approach in the port call emissions Integration of port approach in the port call by* (Doctoral dissertation). TU Delft.

Macharis, C., & Bernardini, A. (2015). Reviewing the use of multi-criteria decision analysis for the evaluation of transport projects: Time for a multi-actor approach. *Transp. Policy*, *37*, 177–186. https://doi.org/10.1016/j.tranpol.2014.11.002

Michaelides, M. P., Herodotou, H., Lind, M., & Watson, R. T. (2019). Port-2-Port Communication Enhancing Short Sea Shipping Performance: The Case Study of Cyprus and the Eastern Mediterranean. https://doi.org/10.3390/su11071912

Mission and Organization - Tanger Med Port Authority. (2022). Retrieved September 30, 2022, from https://www.tangermedport.com/en/port-authority/mission-and-organization/

Mohammadi, M., & Rezaei, J. (2020). Bayesian best-worst method: A probabilistic group decision making model. *Omega*, *96*, 102075. https://doi.org/10.1016/J.OMEGA.2019.06.001

Molkenboer, K. F. (2020). The critical areas of information sharing for improvement of the efficiency of the nautical chain A Port of Rotterdam case study.

Munim, Z. H., Sornn-Friese, H., & Dushenko, M. (2020). Identifying the appropriate governance model for green port management: Applying Analytic Network Process and Best-Worst methods to ports in the Indian Ocean Rim. *J. Clean. Prod.*, *268*, 122156. https://doi.org/10.1016/j.jclepro.2020.122156

Nikghadam, S., Molkenboer, K. F., Tavasszy, L., & Rezaei, J. (2021). Information sharing to mitigate delays in port: the case of the Port of Rotterdam. *Marit. Econ. Logist.*, 1–26. https://doi.org/10.1057/s41278-021-00203-9

Notteboom, T. E. (2006). The Time factor in liner shipping services. *Marit. Econ. Logist.*, *8*(1), 19–39. https://doi.org/10.1057/PALGRAVE.MEL.9100148/FIGURES/5

Port of Antwerp-Bruges. (n.d.). Retrieved June 28, 2022, from https://www.portofantwerpbruges.com/en/our-port/world-port

Port of Hamburg. (2021). Port of Hamburg | Statistics | Container Handling. Retrieved June 23, 2022, from https://www.hafen-hamburg.de/en/statistics/containerhandling/%20https://www.hafen-hamburg.de/en/statistics/containerhandling

PortXchange. (2021). Retrieved June 23, 2022, from https://port-xchange.com/synchronizer/?location=port-of-vado-ligure

Poulsen, R. T., & Sampson, H. (2020). A swift turnaround? Abating shipping greenhouse gas emissions via port call optimization. *Transp. Res. Part D Transp. Environ.*, *86*, 102460. https://doi.org/10.1016/j.trd.2020.102460

Praditya, D., Janssen, M., & Sulastri, R. (2017). Determinants of business-to-government information sharing arrangements. *Electronic Journal of e-Government*, *15*(1), pp44–56.

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega (United Kingdom)*, *53*, 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Rezaei, J., van Wulfften Palthe, L., Tavasszy, L., Wiegmans, B., & van der Laan, F. (2019). Port performance measurement in the context of port choice: an MCDA approach. *Manag. Decis.*, *57*(2), 396–417. https://doi.org/10.1108/MD-04-2018-0482/FULL/PDF

Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *Eur. J. Oper. Res.*, *48*(1), 9–26. https://doi.org/https://doi.org/10.1016/0377-2217(90)90057-I

Schutte, N. ((2020). *Design of collaborative logistics concepts with a value-focused approach* (Doctoral dissertation). Delft University of Technology.

Sirimanne, S. N., Hoffman, J., Juan, W., Asariotis, R., Assaf, M., Ayala, G., Benamara, H., Chantrel, D., Hoffmann, J., & Premti, A. (2019). Review of maritime transport 2019. *United Nations Conf. Trade Dev. Geneva, Switz.*

Talley, W. K. (2009). *Port economics*. Routledge.

Tijan, E., Jović, M., Panjako, A., & Žgaljić, D. (2021). The role of port authority in port governance and port community system implementation. *Sustain.*, *13*(5), 1–14. https://doi.org/10.3390/su13052795

Tongzon, J. L. (2009). Port choice and freight forwarders. *Transportation Research Part E: Logistics and Transportation Review*, *45*(1), 186–195.

Trujillo, L., & Tovar, B. (2007). The european port industry: An analysis of its economic efficiency. *Maritime Economics & Logistics*, *9*(2), 148–171.

UNCTAD. (2021). *Key performance indicators for ports and the shipping fleet* (tech. rep.). https://doi.org/10.18356/9789210000970c008

Van der Lugt, L., De Langen, P., & Hadgorn, E. (2015). Beyond the landlord: worldwide empirical analysis of port authority strategies. *Int. J. Shipp. Transp. Logist.*, 63–84.

Veenstra, A., & Harmelink, R. (2021). On the quality of ship arrival predictions. *Marit. Econ. Logist.*, *23*(4), 655–673. https://doi.org/10.1057/s41278-021-00187-6

Vermeulen, M. (2020). *Identifying and improving port call processes to enable Just-In-Time arrivals and services: A case study on MSC container shipping in the Port of Rotterdam* (Doctoral dissertation). Delft University of Technology. https://repository.tudelft.nl/islandora/object/uuid%7B%5C%%7D3A03213874-8850-4f85-97a7-29fe895fedc4

Vieira, G. B. B., Neto, F. J. K., & Ribeiro, J. L. D. (2015). The Rationalization of Port Logistics Activities: A Study at Port of Santos (Brazil). *Int. J. e-Navigation Marit. Econ.*, *2*, 73–86. https://doi.org/10.1016/J.ENAVI.2015.06.007

WARTSILA. (2019). Port Call Optimisation paves the way towards a higher port performance. Retrieved April 25, 2022, from https://www.wartsila.com/insights/article/port-call-optimisation-paves-the-way-towards-a-higher-port-performance

Watson, R., Holm, H., & Lind, M. (2015). Green steaming: A methodology for estimating carbon emissions avoided.

Wijma, D., Verbraeck, A., Cunningham, S., & Huang, Y. (2018). *Proving the potential impact of data sharing among actors in the port call process through data analyses and discrete event simulation* (Doctoral dissertation). Delft University of Technology.

Winebrake, J. J., Corbett, J. J., & Meyer, P. E. (2007). Energy use and emissions from marine vessels: A total fuel life cycle approach. *Journal of the Air & Waste Management Association*, *57*(1), 102–110. https://doi.org/10.1080/10473289.2007.10465301

World Bank. (2022). *The Container Port Performance Index 2021* (tech. rep.). https://doi.org/10.1596/37538

Yavuz, K. (2011). A proposed innovation strategy for turkish port administration policy via information technology. *Maritime Policy & Management*, *38*(2), 151–167. https://doi.org/10.1080/03088839.2011.556676

Yin, R. K. (2003). Designing case studies. *Qualitative research methods*, *5*(14), 359–386.

A

Scientific paper

Identifying the importance of performance attributes for innovations in Port Call management

M. Schoneveld[1], L.A. Tavasszy[1,2], W.W.A. Beelaerts van Blokland[3], R.M. Stikkelman[1], E.B.H.J. van Hassel[4] and P. Everts[5]

[1] *Delft University of Technology, Faculty of Technology, Policy and Management, The Netherlands*
[2] *Delft University of Technology, Faculty of Civil Engineering and Geosciences, The Netherlands*
[3] *Delft University of Technology, Faculty of Mechanical, Maritime and Materials Engineering, The Netherlands*
[4] *University of Antwerp, Faculty of Business and Economics, Department of Transport and Regional Economics, Belgium*
[5] *KOTUG International, Optiport, Rotterdam, The Netherlands*

Abstract—Port performance is under pressure due to high congestion levels and a need to reduce GHG emissions. The industry is looking for ways to increase efficiency in ports. A promising concept is known as port call optimization where waiting times and turn-around times can be reduced. This research contributes to the body of port call optimization literature by identifying the importance of performance attributes for innovations. Identifying the performance attributes and how stakeholders weight these has never been explored before in literature. The relative importance has been derived using the Bayesian Best-Worst Method. The performance attributes: incidents, near misses, robustness and added value, are most important for evaluating an innovation for port call management. Results on micro level show heterogeneity and homogeneity in preferences for port attributes. Both ports with complex nautical restrictions prefer performance attributes related to safety. The port with centralised management is more commercially driven and there is homogeneity within a port. Furthermore, heterogeneity is seen between stakeholder groups and between port authority (PA). PAs from centralised port value attributes relatively different than a PA with decentralised and licensing activities. Some differences and similarities can be explained by the port contexts. The findings can be used for the design of innovations in port call management. Research could be repeated in other port cases to validate the significance of these results.

Keywords—Port Call Management, Port Call Optimization, Performance Attributes, Preferences for Innovations, Best-Worst Method

I. INTRODUCTION

Ports are important nodes in the global supply chain. These supply chains are responsible for 80% of the total transport flows [1]. The performance of ports plays a crucial role in the global supply chain. Efficient port operation is important for the ports competitive position [2]. Due to disrupted supply chains, the performance of ports is under pressure. Peak congestion due to disrupted supply chains are causing longer waiting times and slower turn-around times for vessels [3]. Congestion of a vessel in or out of the port usually is a result of disruptions and deviations in the port call processes. The IMO Report [4], have estimated that vessels spend up to 9% of their time at anchorage. This is estimated to a demurrage costs of 180 billion USD globally [5]. A second side effect of longer waiting times outside the port is the CO_2 emissions and local effect on air quality around ports when vessels idle their engines. The longer the vessels wait outside the port the longer more fuel they burn and GHG emissions they emit. Managing the port call process is a crucial bottleneck for ports as it can determine port performance and influence these maritime challenges.

One study [6] suggests areas of improvement as voyage efficiencies and port efficiencies. This research focuses on the port efficiencies in the port call process. The considered port call processes are the activities prior, during, and after the visit of a vessel [7]. The involved stakeholders are terminals, port authorities, pilots, tugs, moorers, and shipping companies. Theses activities determine the port performance as it determines the turn-around time of ports. Managing the processes and activities of the port call is described as port call management. UNCTAD suggests three policy measures to improve port performance: Port call optimization, Facilitation, Port operations [8]. Port operations refers mostly to terminal operations and is much researched and often fairly optimised already. Facilitation concerns the physical aspect of building extra infrastructure to accommodate more vessels. Port call optimization is the most promising as it bring extended benefits to the environment [8]. Port call optimization can be described as the process of making the internal port call as efficient as possible according to the needs of the stakeholders [9]. There are several innovations to improve the port call process. Examples can be: data sharing tools, asset optimization, or autonomous nautical agents. Decision making on suitable innovations for port call management can be rather complex because of the involvement of various stakeholders.

To date, research on the interests of stakeholders for evaluating innovations for port call management is lacking. Identifying performance attributes for evaluating innovations in the port call management has never been done before. Before the port call stakeholders adopt innovations for port call optimization, it is important to identify relevant performance attributes and the weights. This leads to better innovation design. This research will contribute to literature by identifying relevant attributes using semi-structured interviews in various ports. Furthermore, this thesis will identify the relative importance of these attributes by performing a best-worst method [10]. To reach these goals the following research question is composed: *"How do stakeholders in different ports value performance attributes for evaluating innovations in port call management"*. Research will be conducted in various port contexts to get a diverse perspective on performance attributes. The findings of this research can eventually support decision-making for innovations in port call management.

II. LITERATURE REVIEW

Literature on port call processes and optimization is not widely studied. Only 24 related articles on port call optimization can be found in the search engine Scopus. From the 24 articles found in Scopus, 11 studies have been identified as relevant. The literature can be divided into quantitative and qualitative research. Generally, port call optimization can be described as the process of making port calls as efficient as possible according to the needs of involved stakeholders [9]. This definition includes external and internal port processes. In this research, port call optimization is referred to the internal processes within a port. In other words, it is about aligning each stakeholder's action with other stakeholders [9]. Furthermore, gray literature describes port call optimization as ships arriving right on time, by effectively communicating with the parties in the port [8]. In such a way that when the vessel arrives, it can directly be berthed without having to wait. With the result of saving waiting time, reducing the turn-around time and reducing total emissions. This section will review the 11 relevant researches on port calls.

a. Quantitative Research

Research on arrival times in ports, shows that shipping liners offer poor and optimistic arrival estimates which are usually inaccurate [11]. Vessel agencies often communicate an exceedingly optimistic arrival time to the port to ensure a berth allocation. As many ports serve vessels in a first come first serve manner, the vessel agency hopes to guarantee a slot. This results in unnecessary waiting time for vessels and poor port performance. The inaccuracies in arrival times is mentioned by several interviewees and studies [12]; [13]. These studies state that inefficiencies usually happen due to lack of information and changes not being communicated.

Besides improvements in time efficiency, port call optimization can also reduce emissions of vessels during a port call [14]. This thesis modelled a control structure based on the information sharing concept of Port Collaborative Decision-Making (PortCDM) to optimally control the speed of incoming vessels and shift the berth time-windows at terminals based on accurate information. The main objective of the optimization is to minimise the maximum deviation between ship being ready and actual start time of operation. The results showed a reduction in total emissions but a slight increase in time spent in port. This is logical as the approach speed can be reduced for incoming vessels. Furthermore, this research presents the sub objectives of different stakeholders in the port call process. Table 1 shows that each stakeholder has different optimization objectives.

TABLE 1: OPTIMIZATION OBJECTIVES ([14])

Stakeholder	Objective
Captain	Vessel arrival and departure without waiting time (depends on cargo type)
Nautical services	Optimal asset use and allocation
Harbour Master	Operations optimised for safety and throughput
Terminal operator	Berth utilization

Virtual Arrival Schemes are used to match the vessels arrival time to resource readiness of the port. The idea is that vessel's speed can be optimised during the voyage to meet revised arrival times at ports [14]. With the use of this specific model the total emissions were reduced significantly, however the time increased slightly. This is an important trade-off vessel agencies have to make. Such research is often referred to as just-in-time (JIT) arrival by the [15]. According to [6], this policy did not advance in the industry because there are sharp financial incentives not to delay a vessel. On top of that a problematic relationship with fear of losing port services in 'first come, first serve' system. Another vessel may be able to pick your port slot, leading to more delays in ports. Thus probably the order the port serves vessels can be an important port factor influencing the port call optimization.

Port call optimization is likewise studied in the concept of JIT arrival to optimise the speed during voyage to arrive at the port when the availability of berth and nautical service providers are ensured [16]. This study is performed by Marine Traffic and the results show that a fuel saving of 14% can be reached if the voyage is optimised from pilot boarding place to pilot boarding place. Optimisation for vessel voyages 24 hours and 12 hours prior to arrival of pilot boarding place also show substantial savings. The optimization of vessel voyages is out of the scope of this research as this research focuses more on the internal port processes. JIT arrivals however also emphasises collaboration in terms of data sharing between shipping lines, ports and terminals to realise the benefits [16].

The main cause of inefficiencies can be improved if the

operations during a port call would be more predictable and communication between parties would be more transparent [17]. Simulation models have described the key processes of the port call and simulated possible interventions for the Port of Rotterdam (PoR) [18]; [19]. These interventions are more collaboration solutions that share the vessel's PTA and ETA with stakeholders involved. Simulations have shown that more sharing of vessel's PTA and ETA with everyone can decrease the turn-around time [18]. Data analysis from deep-sea vessels in the PoR have shown that waiting time accounts for the largest part of turnaround time in a port. Furthermore, the unavailability of nautical service providers will profoundly increase the vessel waiting time at anchorage ([20]).

b. Qualitative Research

The first qualitative research presents a framework to help analyse and understand the barriers and drivers of port call digitalization [21]. Drivers and barriers were explored in two different ports in Northwest Europe. Most identified drivers and barriers are related to ecosystem level, meaning one port was more keen on collaborating and participating in developing digital platforms than the other port. The identified drivers and barriers are collected through semi-structured interviews. The most common driver was to use digitalization so that is generates value for themselves and the customer. The most common barrier was that digitalization poses a threat to their business by fewer activities. It will be interesting to see if such barriers reflect the given preferences.

A re-occurring topic concerning port call optimization is collaboration. [7] defines it as aligning all the stakeholders involved in the nautical services. He suggests information sharing protocols for how and with whom to share what information during a port call. Similarly, the International Task Forces of Port call optimization are settling on standards for universal use of definitions. These standardised definitions are important for standardised communication between vessel and port. It is first step towards port call optimization. Collaboration in the form of information sharing has been research in the PoR [22]. The conclusion was that terminals are often not up to speed with the nautical situation and the other way around. Different communication tools are used making communications threads instead of a good network. Communication about operational updates goes through phone calls or VHF-radio for internal communication and between organisations. This leads to information being missed and operators taking incorrect decisions. It generally leads to a reduced situational awareness.

Another qualitative case study in Cyprus and Mediterranean harbours found KPI's like arrival punctuality, berth waiting, and berth utilization to investigate the factors influencing the various waiting times. The analysis revealed a considerable variation in agent performance regarding the KPI's ([23]). Similar findings of the more quantitative studies of [11]. They suggest using port-2-port communication of the PortCDM concept. Furthermore, sharing data and transparency among involved stakeholders in a port call is proposed.

c. Conclusion

First of all from qualitative research on port call optimization identified inefficiencies have been pointed out [11]. The causes and problems in port call processes vary per case but mainly come down to poor communication and delays of services in the port call. Which results in unnecessary waiting time for vessels and poor performance for ports. Suggestions to mitigate these delays have been done in form of voyage speed optimization and JIT arrivals [14][4][16]. Such interventions do show positive effects on waiting times and emissions.

Secondly, literature with a qualitative approach is slightly more dominant. It can generally be concluded that there is a need for more situational awareness for all parties involved. Increasing situational awareness will increase collaboration. In literature mitigating delays in the port call process is often referred to port call optimization [24]; [25]. Optimising the port call process can be rather complex due to the amount of stakeholders involved. Suggestions have been made about information sharing and collaboration in ports [6]; [22]. Concepts like PortCDM has proven to benefit the efficiency of the port call [12]. Optimizing the port call is a motive to increase the performance of a port.

Port call optimization is still fairly new in research. Out of 24, 11 studies have been reviewed on port call optimization. Port call optimization can be reached through several measures. The industry is developing several innovations to help the port call performance. However as described the port call is rather complex, with many various stakeholders having different interests. When designing or deciding on suitable innovations for port call management it is important to identify performance attributes and their relative importance. To date one research has been found which has reported several optimization objectives of stakeholders in port call optimization [14]. Never before have performance attributes been identified for assessing preferred port call innovations. This research will identify relevant performance attributes and research how stakeholders weight these performance attributes. This research will contribute to this gap in the literature. The findings will not only be beneficial for the design and decision-making of innovations, but it can also help understand how stakeholders weight attributes differently.

III. METHODOLOGY

The goal of this research is to find the importance of performance attributes for evaluation of innovations in port call management. The port call is a complex environment with many stakeholders involved. The success of an innovation for port call optimization is dependent on the interests of stakeholders. The attributes and its importance determine reflect the preferences of stakeholders for evaluating innovations. A Multi Criteria Decision-Making (MCDM) model is a good analysis for making decisions in a multi-actor and multi-criteria setting [10]. A MCDM can evaluate a number

of innovations for port call management with respect to certain performance attributes.

This research follows 3 steps based on a typical Multi-Criteria Decision Making (MCDM) problem (figure 1). The first step is to identify the performance attributes for assessing innovations in port call management. To date, the performance attributes are unknown and are identified through semi-structured interviews. The semi-structured interviews are conducted with a wide range of stakeholders active in the port call processes. Semi-structured interviews have been conducted with 12 experts from the 6 different port cases. Representatives from the port authority, tug operator, a terminal, a mooring company, and a shipping company have been contacted. The ports vary in terms of cargo, volumes, geographical and organisational structure. The ports also diversify in terms of the continent they are located. Variation in ports is desirable because it gives a wide perspective on what performance attributes are relevant.

The second step is to collect the relative importance (weights) of the relevant performance attributes. Among the MCDM steps, there are several methods to obtain the weights of performance attributes. The Best-Worst Method (BWM) and Analytic Hierarchy Process (AHP) are most common [26]. The BWM is the chosen method for obtaining the weights of attributes, because it requires less data and it leads to more consistent comparisons [10]. The method uses pairwise comparisons with the best and worst attributes to determine the weights. This mitigates anchoring bias of the decision-maker [27]. The data of the pairwise comparisons is collected through a BWM survey. Stakeholders from the semi-structured interviews are asked to fill in this survey.

The third step is to determine the weights of the performance attributes. The BWM method has several variations on calculating the weights. The Bayesian BWM is a suitable method as it finds the optimal weights based on a group of decision-makers [28]. When calculating the optimal weights for several decision-makers, the aggregated average is often calculated using the arithmetic mean. This is however sensitive to outliers. The Bayesian method uses probabilistic distributions to compute the averages at once. The input of the Bayesian BWM are the pairwise comparison from the survey. The weights are determined following the 5 steps described in the paper [28]. The weights of the attributes represents the relative importance of the attributes. A valuable feature of the Bayesian BWM is that it provides credal ranking. This enables to measure the degree of confidence to which a group of decision-makers prefer one criterion over another.

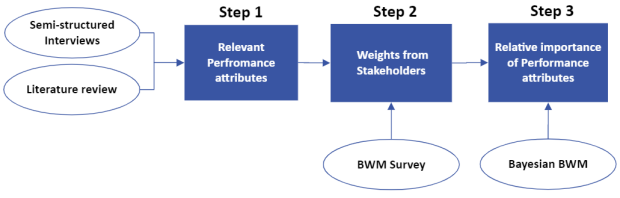


Fig. 1: Research Methodology

IV. System description

This research studies the processes of a port call. The process generally starts when the vessel first makes contact with the Vessel Traffic Service (VTS) of the port and ends when it leaves the VTS area of the port. This process has been conceptually represented in a metro map showing the involved stakeholders and activities during a port call (figure 2)[29]. The processes are mainly focused on the nautical and port activities needed to complete a port call. Each coloured line represents a stakeholder and the white nodes represent a main activity in the port call. The studied stakeholders are: port authorities (PA), pilots, tugs, moorers, terminals, and shipping companies. The main activities are: Vessel arrives at pilot station, arrives at tug station, arrives at berth, cargo operations, departure berth, departure tug zone, departure pilot station. Each activity requires collaboration and coordination of stakeholders involved. The processes are intertwined, meaning they are dependent on each other. If one activity is delayed it effects the rest of the port call. The processes illustrated in figure 2, define the scope of this research. This research is mainly focused on the nautical activities of manoeuvring a vessel in and out of a port. Activities like bunkering, surveying, loading is not focused on.

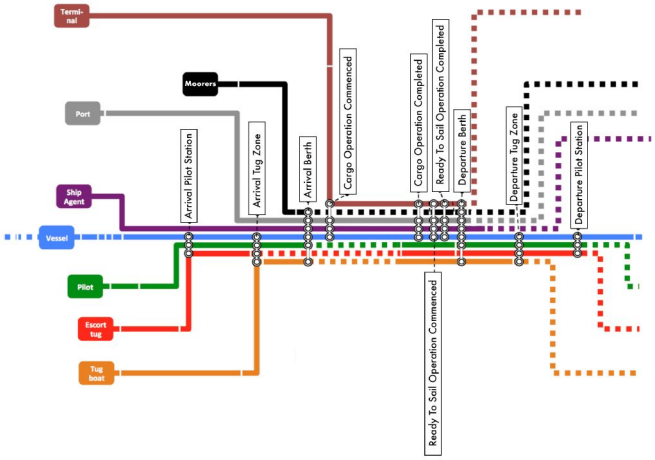


Fig. 2: Port call processes [29]

This figure describes the general process of a port call. From the interviews with stakeholders in 6 different ports it can be said that port calls are organised slightly differently depending on port's environment. The ports have different management structures, roles of PA, stakeholders involved, industries, nautical restrictions, explaining it's environment. These are factors that have influence on how the port call is organised. The higher the amount of stakeholders involved the more interdependies there are and the more difficult it is to organize the port call. Also multiple commodities in one port can make a port call more complex as there are more industries with different needs. The role of the port authority and it's management structure has influence on the organisation of the port call [30][31].

V. Performance attributes and relative importance

The first goal of this research was to find relevant performance attributes for evaluating innovations for port call

management. As became clear from the literature review, performance attributes for evaluating innovations in the port call process has never been explored before. One study has stated the optimization objectives of the stakeholders for port call optimization [14]. A captain's objective is to minimise the waiting time of a vessel, the nautical services want to utilise their assets optimally, and the harbour master want operations optimised for safety and throughput. From this single study four different objectives are identified (table 1) with different interests. As this is the only literature piece related to performance attributes that could be used for evaluating innovations for port call management, attributes should be found from the semi-structured interviews.

In total 14 interviews were held with involved stakeholders from different ports. Interviewees were asked about what criteria and KPIs are important to them when evaluating port call innovations. This has led to a total of 65 criteria which were mentioned at least by two interviewees. The relevant performance attributes have been chosen such that they are relevant to all stakeholders. For example, attributes like fuel consumption and berth utilization are stakeholder specific. It has lead to a total of 17 attributes categorised into 3 groups. 4 attributes can be classified as commercial attributes, 9 attributes can be classified as operational attributes, and 4 attributes can be classified as safety attributes.

TABLE 2: OVERVIEW RESPONDENTS BWM SURVEY

No.	Stakeholder	Port
1	Port Authority	RAK Ports
2	Port Authority	RAK Ports
3	Port Authority	Port Antwerp-Bruges
4	Port Authority	Port Sydney
5	Port Authority	Port Tanger-Med
6	Tug Operator	Port Antwerp-Bruges
7	Tug Operator	Port of Port Arthur
8	Tug Operator	Port of Port Arthur
9	Tug Operator	Port Sydney
10	Pilot Organisation	Port of Port Arthur
11	Terminal	Port Antwerp-Bruges
12	Shipping Company	-

The interviewed stakeholders have been asked to give input of the BWM survey. In total 12 respondents have provided input (table 2). For determining the relative importance the Bayesian BWM is computed. The weights represent the relative importance, these can be analysed on macro and micro level. Macro level is the aggregated sum of all respondents, representing the relative importance of performance attributes for the broader industry. On micro level the respondents are analysed more individually. This can give ideas about the relative importance of performance attributes for individuals or smaller groups.

a. Results on macro level

The results lead to following preference order (from most important to least): Safety effects, Operational effects, Commercial effects. Overall the safety effects are scored as most important according to all the involved stakeholders. It can be concluded that safety is a very important aspect in port call management. The performance attributes: incidents (0.144), near misses (0.100), robustness (0.102) and added value (0.089), are most important for evaluating an innovation for port call management. Near misses are the amount of near miss reports, robustness is how resilient to users and prone to errors a innovation is, and added value is the value a innovation brings. The most mentioned performance attribute was related to time during the interviews. This attribute is overall scored half as important as the most important attribute. On the other hand added value can indicate it is important the innovation brings value of some sort. The least important criteria are user-friendliness (0.030) and flexibility (0.035). Flexibility is a logical score as it is suggested to fit an innovation to the specific port case.

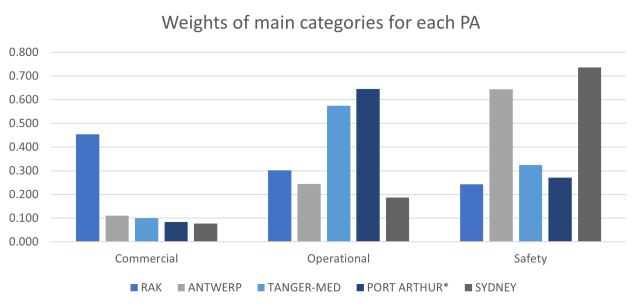


Fig. 3: Weights of categories from Port Authorities

b. Results on micro level

When analysing the results on micro level, it can be concluded that their is heterogeneity and also homogeneity in how the stakeholders weighted the performance attributes. One notable result is that the PA of port Tanger-Med is the only stakeholder to weight operational attributes (0.575) higher than the other PAs. Another notable result is the strong preference for commercial attributes (0.454) by the PA of RAK Ports. Shipping industry is the only stakeholder to weight environmental effect relatively higher than others. These are examples of heterogeneity in how PA and individuals weight the performance attributes (figure 3 & 4).

Homogeneity is found within the ports of Antwerp-Bruges and port of Port Arthur. The stakeholders value safety attributes as most important. There is no big conflict in interests in these ports for evaluating innovations in port call management. The stakeholders in port Antwerp-Bruges and port of Port Arthur score very similar with both incidents as most important attribute and OPEX as least important. These ports both have complex nautical restrictions and are decentralised. The complex nautical restrictions could explain the high safety preference. Homogeneity is also seen within RAK Ports. This is logical as they have a centralized management structure.

VI. CONCLUSION

This research has contributed to the literature of port call optimization by identifying relevant performance attributes for evaluation of innovations in port call management. This research has also researched how stakeholders weight the performance attributes. The results on macro level show

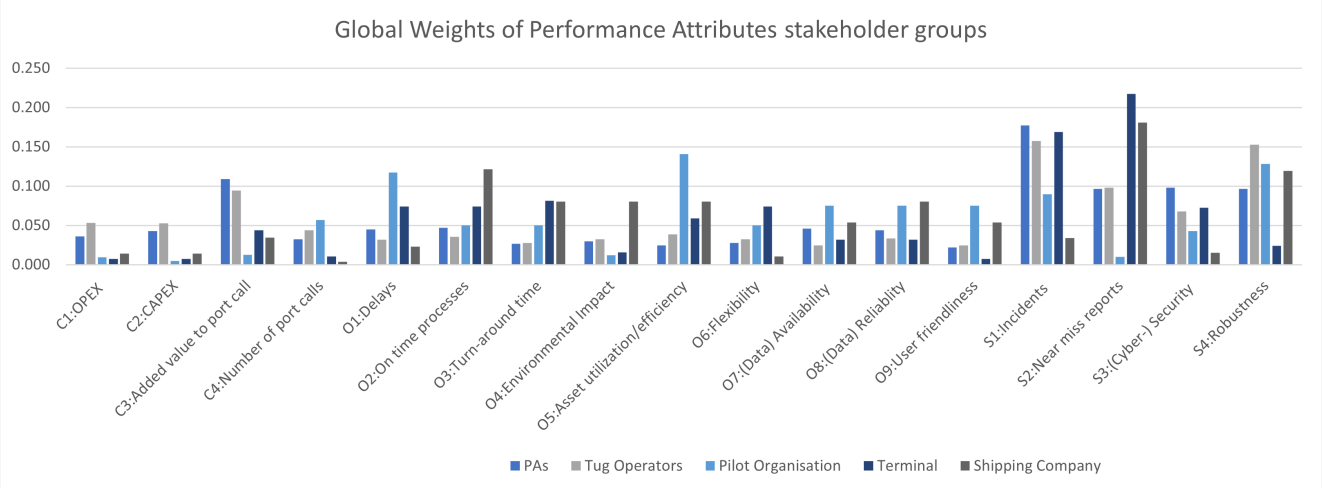


Fig. 4: Weights of performance attributes from stakeholder groups

a relatively higher importance for safety attributes. The safety aspect during port call management can be considered most important. Thus an innovation performing well on attributes: Incidents, near misses, robustness, and added value will generally be preferred. An innovation generally does not have to be flexible as this is scored as least important attribute. The results on micro level shows some heterogeneity and homogeneity. It can be concluded that the performance attributes are preferred differently by the port call stakeholders. Heterogeneity can be found in how PAs weight performance attributes. This means the PA of ports have different preferences compared to each other. Heterogeneity is also found between stakeholders. Homogeneity in preferences of performance attributes is seen within and between ports Antwerp-Bruges and port of Port Arthur. In both ports the safety attributes are relatively more important. Both ports have complex nautical restrictions which could explain the higher preference for safety.

The results show that stakeholders from various port cases weight performance attributes differently. Heterogeneity and homogeneity in results could be explained by the context of the port, in some cases. The homogeneity of Port Antwerp and port of Port Arthur, with high preference for safety attributes, could be explained by the complex nautical restrictions they both have. The strong operational preference of the PA of Port Tanger-Med could be explained by the role of the PA and licensed services. The strong preference for commercial attributes of RAK Ports could be explained by the centralized management and active role of the PA.

The contribution of this research is providing a novel set of performance attributes for evaluating innovations in port call management. Another contribution is speculating about the causes of heterogeneity in stakeholder's preferences. These two contributions have never been identified in literature. More practically, the performance attributes and relative importance can be considered for design of port call innovations. Further research is recommended in evaluating innovations in ports to measure the effects of innovations. Such study can be done through agent-based modelling or discrete simulations.

VII. Discussion

Identifying and understanding the performance attributes and their weights can lead to better design for port call optimization. If the design is a better fit, operations within port call management run more efficient. Then port call optimization is more likely to be effective and address the maritime challenges; reducing peak congestion in ports and reduce waiting times and thus GHG emissions.

Generally it can be argued that the preferences of actors are influenced by the port's contexts. It is speculated that the management structures, involvement of PA, number of stakeholders, industries, congestion, nautical restrictions can explain certain heterogeneity in the results. Involvement of PA and industries have already been pointed out in literature to have affect on port call optimization. Unfortunately due to a lack in respondents statistical significance is difficult to determine. Meaning some of the results could also be influenced by interpretation, biases or coincidence. On the other hand the individual responses can be classified reliable as the consistency ratios were close to 0.

Reflecting on the research method, the categorisation of attributes could be argued. Some operational attributes are correlated with commercial attributes. For example, a higher asset utilization increase number of port calls and added value. The attributes could have been categorised into costs, service, system requirements, safety, and environment. The 17 attributes would have been divided more equally in size. One could argue that these categories don't have the same hierarchical level. For this reason it is chosen to combine attributes into higher hierarchical categories. This does lead to one category with 9 attributes. Lastly, the BWM results have a temporal dimension meaning the results are time related.

Future research can be recommended to address the mentioned limitations of this research. Research could be repeated for other port cases to add to the body of knowledge. Repeating the BWM in other ports can build upon statistical significance of clarifying the differences and similarities

in weights by port contexts. Further research can be recommended in exploring the performance of an innovation in suitable port through simulation study. Simulation study can study the real world effects of an innovation.

REFERENCES

[1] S. N. Sirimanne, J. Hoffman, W. Juan, R. Asariotis, M. Assaf, G. Ayala, H. Benamara, D. Chantrel, J. Hoffmann, and A. Premti, "Review of maritime transport 2019," in *United Nations Conf. Trade Dev. Geneva, Switz.*, 2019.

[2] J. L. Tongzon, "Port choice and freight forwarders," *Transportation Research Part E: Logistics and Transportation Review*, vol. 45, no. 1, pp. 186–195, 2009.

[3] UNCTAD, "Key performance indicators for ports and the shipping fleet," Tech. Rep., 2021.

[4] IMO, "Just In Time Arrival Guide - Barriers and Potential Solutions," Tech. Rep., 2020. [Online]. Available: https://wwwcdn.imo.org/localresources/en/OurWork/PartnershipsProjects/Documents/GIA-just-in-time-hires.pdf

[5] L. Brand, "Storing vital products with care - Vopak," in *Smart Marit. Conf.*, 2022. [Online]. Available: https://smartmaritimenetwork.com/wp-content/uploads/2022/05

[6] C. F. Broersma, "Abating GHG Emissions with Dynamic Arrival Times," Ph.D. dissertation, Delft University of Technology, 2021.

[7] M. Lind, S. Haraldson, M. Karlsson, and R. T. Watson, "Port Collaborative Decision Making – Closing the Loop in Sea Traffic Management," *14th Int. Conf. Comput. Appl. Inf. Technol. Marit. Ind.*, no. 2009, pp. 499–515, 2015. [Online]. Available: http://monalisaproject.eu/wp-content/uploads/Compit-2015-Port-CDM-Lind.pdf{%}0Ahttps://pdfs.semanticscholar.org/ce1b/4e555d67e957e407944c6fbb7e69c6c4f5bb.pdf

[8] WARTSILA, "Port Call Optimisation paves the way towards a higher port performance," 2019. [Online]. Available: https://www.wartsila.com/insights/article/port-call-optimisation-paves-the-way-towards-a-higher-port-performance

[9] M. Lind, M. Bergmann, S. Haraldson, R. T. Watson, J. Park, J. Gimenez, and T. Andersen, "Port Collaborative Decision Making (PortCDM): An enabler for Port Call Optimization empowered by international harmonization," no. January, 2018.

[10] J. Rezaei, "Best-worst multi-criteria decision-making method," *Omega (United Kingdom)*, vol. 53, pp. 49–57, jun 2015.

[11] A. Veenstra and R. Harmelink, "On the quality of ship arrival predictions," *Marit. Econ. Logist.*, vol. 23, no. 4, pp. 655–673, 2021. [Online]. Available: https://doi.org/10.1057/s41278-021-00187-6

[12] M. Lind, M. Bergmann, N. Bjørn-andersen, W. Robert, S. Haraldson, R. Watson, T. Andersen, M. Michaelides, N. Evmides, N. Gerosavva, M. Karlsson, H. Holm, E. Olsson, A. Zerem, H. Herodotou, G. Ferrus, J. Gimenez, J. Arjona, M. Marquez, T. Rygh, S. Voskarides, and A. Gonzales, "Substantial value for shipping found in PortCDM testbeds by 30 th of March 2019," vol. 2019, no. March, 2019.

[13] S. Nikghadam, K. F. Molkenboer, L. Tavasszy, and J. Rezaei, "Information sharing to mitigate delays in port: the case of the Port of Rotterdam," *Marit. Econ. Logist.*, pp. 1–26, nov 2021. [Online]. Available: https://link.springer.com/article/10.1057/s41278-021-00203-9

[14] J. W. Lokin, "Integration of port approach in the port call emissions Integration of port approach in the port call by," Ph.D. dissertation, TU Delft, 2022.

[15] IMO, "IMO and the Sustainable Development Goals | IMO," *IMO Sustain. Dev. goals*, 2020. [Online]. Available: https://www.imo.org/en/MediaCentre/HotTopics/Pages/SustainableDevelopmentGoals.aspx

[16] IMO and N. Roumelioti, "Just In Time Arrival - Emission reduction potential in global container shipping," IMO, Tech. Rep., 2022. [Online]. Available: https://greenvoyage2050.imo.org/wp-content/uploads/2022/06/JIT-Container-Study.pdf

[17] D. Wijma, A. Verbraeck, S. Cunningham, and Y. Huang, "Proving the potential impact of data sharing among actors in the port call process through data analyses and discrete event simulation," Ph.D. dissertation, Delft University of Technology, 2018.

[18] I. Y. Davydenko and R. W. Fransen, "Conceptual Agent Based Model Simulation for the Port Nautical Services," *IFAC-PapersOnLine*, vol. 52, no. 3, pp. 19–24, jan 2019.

[19] R. Fransen and I. Davydenko, "Empirical agent-based model simulation for the port nautical services: A case study for the Port of Rotterdam," *Marit. Transp. Res.*, vol. 2, jan 2021.

[20] Z. Gan, "Simulating the Nautical Chain of Operations in the Deep-Sea Port," Ph.D. dissertation, Delft University of Technology, 2019. [Online]. Available: http://resolver.tudelft.nl/uuid:03ad40c4-bd5e-4b8a-a3b4-22b04e09a19f

[21] M. Imset, "Drivers and barriers for the involvement of port agents in digital transformation of port ecosystems Lizbeth Salas Nordli," in *Reconnect, Rediscover, Reimagine*, no. December, Valencia, 2021.

[22] K. F. Molkenboer, "The critical areas of information sharing for improvement of the efficiency of the nautical chain A Port of Rotterdam case study," 2020.

[23] M. P. Michaelides, H. Herodotou, M. Lind, and R. T. Watson, "Port-2-Port Communication Enhancing Short Sea Shipping Performance: The Case Study of Cyprus and the Eastern Mediterranean," 2019.

[24] M. Lind, H. Becha, A. Simha, S. Erik Larsen, E. Ben-Amram, and M. Gnass, "Port Call Optimization: Two Sides of the Same Coin," feb 2021. [Online]. Available: https://www.maritime-executive.com/editorials/port-call-optimization-two-sides-of-the-same-coin

[25] R. T. Poulsen and H. Sampson, "A swift turnaround? Abating shipping greenhouse gas emissions via port call optimization," *Transp. Res. Part D Transp. Environ.*, vol. 86, p. 102460, sep 2020.

[26] T. L. Saaty, "How to make a decision: The analytic hierarchy process," *Eur. J. Oper. Res.*, vol. 48, no. 1, pp. 9–26, 1990. [Online]. Available: https://www.sciencedirect.com/science/article/pii/037722179090057I

[27] J. Rezaei, "Best-worst multi-criteria decision-making method: Some properties and a linear model," *Omega (United Kingdom)*, vol. 64, pp. 126–130, oct 2016. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0305048315002479

[28] M. Mohammadi and J. Rezaei, "Bayesian best-worst method: A probabilistic group decision making model," *Omega*, vol. 96, p. 102075, oct 2020.

[29] M. Lind, S. Haraldson, M. Karlsson, and R. T. Watson, "Overcoming the inability to predict-a PortCDM future," in *10th IHMA Congr. Port Mar. Oper. Vancouver, Canada*, 2016.

[30] M. Lind, R. Ward, and M. Bergmann, *Digitalizing the port call process*, 2020, no. 1.

[31] L. Van der Lugt, P. De Langen, and E. Hadgorn, "Beyond the landlord: worldwide empirical analysis of port authority strategies," *Int. J. Shipp. Transp. Logist.*, pp. 63–84, 2015.

B

Interviews

Interview template
In many port calls the lack of information sharing or incorrect information sharing leads to vessels or nautical services having to wait on each other. With the rising trade volumes and disruptions in the supply chain there is a need for optimized port call operations. Ways to optimize port calls are currently being researched and even tested in some ports. Methods for optimization can be a platform to share data, a tool to plan services more efficiently or other policies. However, due to the complexity of the port call the preferred solution will probably differ per port. The question is what factors determines these differences in a port call? My thesis will try to identify what context factors in ports have an influence on the ability to optimize a port call.

Interviews will be conducted in three different ports to compare the differences and similarities. The aim of these interviews is to understand what the differences are between the ports in terms of port calls. I want to see if there are differences in port call operations and in the management of a port. Thus in this interview I will ask questions about how the port call is organized and the ports role in the port call. It is preferred to answer the questions from the perspective of your organisation. Furthermore I am also interested in your opinion about port call optimization.

Your participation is valuable in gain an understanding of the port call processes in your port. Once I get a understanding how the port authority operates in the port I can conduct a comparative analysis. The answers you give will be summarized and sent to you for a check. Answers will be handled with confidentiality and your name and company name will be made anonymous in my report. After the round of interviews I would like to ask you to fill in a short survey on what port call optimization solution you think will perform best.

Questions for Port Authority

1. Could you introduce yourself?
2. Do you agree that this interview is summarized and that your inputs on port call optimization is used for academic purposes? Your name and the companies name will be made anonymous in my report. The report will not be published in media. *Case description*
3. Who is responsible for planning the port call operations?
4. Are the actors involved the same as in this figure?
5. What is the biggest bottleneck of the port call (no internal issues)? Is there a need for port call optimization?
6. How are incoming and departing vessels served? Who gets priority? First-come first serve?
7. What is your role in efficiently letting vessels berth and departure?

   Context factors
8. What role does the Port Authority take in the port (Landlord model, full service)? How does this effect the planning of the port call operations?
9. Under what contract type are the nautical services providers operational in the port? (Licensed, concession, free market) Are there any regulations you set to the nautical service providers in terms of pricing or operations?

10. What role do you take as port authority during the process of a port call? Is there Centralized or Decentralized Management? How do you belief this influence the port call?
11. Is the size of the port dependent on the ability to optimize the port? How?
12. What other port content factors could have a positive or negative influence on the port call processes?

Identifying objectives

13. During a port call, what are the objectives in terms of efficiency?
14. During a port call, what are the objectives in terms of Safety?
15. During a port call, what are the objectives in terms of Level of service?
16. During a port call, what are the objectives in terms of Sustainability?

Port call optimization

17. What would be a good solution to improve the port call? Why is that solution not yet implemented?
18. Who should take the lead in port call optimization?
19. What would have to change in order to advance port call optimization?
20. What kind of challenges may emerge for the involved actors if port call optimization will advance further?

Questions for Nautical Service Providers

1. Could you introduce yourself?
2. Do you agree that this interview is summarized and that your inputs on port call optimization is used for academic purposes? Your name and the companies name will be made anonymous in my report. The report will not be published in media.

case description

3. What is your companies role in arrival and departure processes of
4. What do you consider to be the bottleneck of the port call (no internal issues)? Within the port call process
5. How do you schedule your activities of the port call processes?

Context factors

6. Processes of the linesmen, pilots, tugboats are quite dependent on each other. What information do you share with other actors? and how is this information currently shared?
7. How many tugboat companies, linesmen, pilots are there in the port? How do you define their business relationship in terms of being competitive or cooperative?
8. How is your organization contracted within the port (Free market, Concession, licensed)? How does this effect how you schedule/operate your processes?
9. Are there level of service requirements from the port authority your company has to comply with? What level of freedom do you have in scheduling your own operations?
10. What other port content factors could have a positive or negative influence on the your processes?

Identifying Objectives

11. What level of freedom do you have in determining your own KPIs, goals, objectives?
12. For your company, when performing activities for the port call, what are your companies objectives in terms of efficiency?
13. For your company, when performing activities for the port call, what are your companies objectives in terms of Safety?
14. For your company, when performing activities for the port call, what are your companies objectives in terms of Level of service?

Port call optimization

15. What do you consider to be a good solution to improve the port call? Why is that solution not yet implemented?
16. Who should take the lead in port call optimization?
17. What would have to change to the way a port call is organized in order to advance port call optimization?
18. What is your opinion on collaboration in terms of sharing more data to advance to a more optimized port call? Why wouldn't this work or why would it work?
19. What kind of challenges may emerge for the involved actors if port call optimization will advance further?

B.1 Interviews RAK Ports

B.1.1. PA Group harbour master

Date: 17 June 2022

1. Is it oke to transcribe this interview? Yes that is fine.

3. Who is responsible for planning the port call operations?

At RAK Ports we have an Operations and a Marine department to coordinate a port call. So our clients they contact the operations department to export a volume of dry-bulk with a certain charter. The operations department will then plan the berth availability and cargo handling. Then we (Marine) receive a vessel booking several days to three weeks in advance usually from the Marine Agent. As time reaches closer to the ETA of the vessel the ETA becomes more accurate. When the vessel arrives it usually goes to anchorage area and when the berth is available we call the vessel to the pilot berth area. Then the pilot boards the vessel and takes the vessel in. The Tugs escort the vessel and the moorings men secure the vessel at berth and then cargo operations can begin. We as Marine department are responsible to make sure all services for berthing a vessel run smoothly.

4. Are any other actors involved in the port?

At RAK Ports all the activities in the port fall under the port authority. The tugs, Pilots and linesmen are operated, controlled and organised by the Marine department.

5. What do you consider to be the bottleneck within the port call? Is there a need for port call optimization?

That's a difficult one… We only have one pilot working at a time. We never have more than one pilot because they are expensive and there is no need to have more. The channel is too narrow to allow for two ships to enter or exit at the same time. It can happen with a small vessel, barge or Pilot Exemption Certificater holder (PEC) that there are two ships manoeuvring the same time. We have enough tug capacity to allow for this.

I would say there that the port calls are already well optimised. Of course there is always room for improvement however these are minor things. Not things that are considered as delays. Because only one ship is handled at a time the planning works quite efficiently. The berths are utilized very efficiently. It is only sometimes that many vessels arrive at once and must wait for a berth to become available. This does not justify an increased capacity for just these few times several vessels arrive at once.

6. How are incoming and departing vessels served? Who gets priority? First-come first serve? It is generally first-come first serve. Sometimes it happens that there is a slight shift in order because of berth availability or priority of cargo.

7. What role does the Port Authority take in the port (Landlord model, full service)? How does this effect the planning of the port call operations?

AFTER EXPLAINATION, Yes I think you can describe our port as a full service port if that means everything is owned and run by the port authority. The port is a private port owned by the Ras Al Khaimah government. All the assets and operations in the ports are run by us. Because everything is run through us it makes it easier to coordinate with the departments. This is one of the reasons why the port call operations run so efficiently.

8. Is information being shared between departments? What information do you share with other actors?

All the necessary communications and information is shared between Marine and Operations. We have contact with the captain of the vessel about the ETA and the time to enter the pilot boarding area. Operations decide on the order of vessel berthing and Marine contact the vessel to arrange the timings and marine services. The information is always quite accurate. The port has recently invested in

digitized operation systems Port Operating System (POS) and a Port Community System (PCS), with information accessible to relevant Port Departments and external Stakeholders.
9. Is the size of the port dependent on the ability to optimize the port? How?
Yes I think so, A port like the Port of Rotterdam is very much spread out and there are a lot of different industries with different terminals. This can make it more complex to organize the operations when there are multiple stakeholders.
10. How come your port is already working so efficiently?
Well I think that I because of our history. The port dates back to easy 1970's and has been growing eversince. The focus has always been on efficiency.
11. What other port content factors could have a positive or negative influence on the port call processes? The weather is an important one. If the weather is too rough it can cause delays. Having sufficient well trained personnel and good quality assets is very important to keep the job moving.
12. What level of freedom do you have in determining your own KPIs, goals, objectives?
This is related to what ever the goals are of the port. This is to have a maximum amount of cargo handled per year. That relates to handling as many ships as possible. For our department you can have KPI's in terms of costs, Efficiency, and safety. New initiatives and revenue streams also direct KPI's.
13. During a port call, what are the objectives in terms of Costs? Costs made by marine services.Efficiency to maximize revenue.
14. During a port call, what are the objectives in terms of Efficiency? - Amount of ships handled per year
- Quickly executed operations with the optimal assets to handle movements
- Avoiding damage and Marine incidents
15. During a port call, what are the objectives in terms of Safety? - Zero injuries,fatalities and damage.
16. During a port call, what are the objectives in terms of Sustainability?
Always to operate assets at the most efficient in terms of fuel efficiencies thereby reducing emissions. Avoidance of pollution incidents.
17. What would be a good solution to improve the port call? Why is that solution not yet implemented?
That's a good question… We are always looking for ways to improve. I can give on example, we have developed an application that accurately maps the depth of our port during tidal times. This gives us more insight into the draughts of the vessel during specific time windows. This then allows our customers to load more bulk during certain time windows. More load per ship means that it can reduce the amount of shipments and thus reduce emitted CO2.

B.1.2. PA Port Manager

Date: 26 July 2022
1. How does your port work?
We have a very short gateway. It can sometimes take only 45 minutes to pickup from anchorage to being at berth. Tidal restrictions are there but not massively impactful. We typically only have like two vessels a day coming in. We use Dynamic underkeel clearance to monitor the depth and load the appropriate amount of bulk. We strive to do the best for the port. Not whats best for the client.
2. How does your port compare to others in terms of operations and organization?
We are the larger multi-commodity dry bulk port in the area. The limestone mining is done very close by which means we are very efficient in terms of costs and handling time.
3. According to you what are the challenges in your port?
The sequence of the vessels coming in is very unpredictable. Sometimes a vessel agency gives ETAs that are never possible. They do this in the hope to get an earlier slot. We serve the vessels as they arrive. First come first serve. So we don't work like that. We could switch to bookings but we have a low valuable product. If we have booked slots and vessels don't show up then we have to wait. For this reason we have require our clients to have 60% of the bulk in the port and the other 40% can be delivered as the vessel is berthed.
We also see that the vessels are bundled up in the same window. The time window is usually 5 days, this means it difficult to book and hold slots. Someone will have to wait. So we will remain with the first come first serve.

5. In terms of port call operations what innovations would be necessary?
We are working on digitalization. Currently we have new PCS and a port operations system. However sometimes it is difficult to get our clients onboard because they don't have the same level of digitalization. Example of truck driver having an old Nokia phone. Putting GPS on all 3000 trucks will give insights on our port stock levels. We can plan the stocks much better. Which will definitely have more financial benefit than the investment is.
How does this new PCS help the marine department?
It helps them with receiving the correct documentation. So the marine operator will only have to go into one system. Without the marine department taking emails and fileing it. Also less paper work. The system will also send notifications to the vessel agencies about the berthing. It can also give a estimated time of cargo completion.

6. What kind of criteria are important to you when assessing an (soft/hard) innovation? Operational, safety, efficiency, costs?
- Cost effective – benefit has to overcome the investment
- Add value to the port
- Efficient – It should safe time
- Safe
- User friendly (multi language)

B.1.3. CEO
Date: 25 July 2022

1. Welke aspecten maakt de haven van RAK uniek? Wat zijn de verschillen tussen RAK Ports en Port of Rotterdam?
Hier in RAK Ports hebben wij een gecentraliseerde aansturing. De haven autoriteit heeft zeggenschap over de gehele haven. In Rotterdam is dit meer gedecentraliseerd. Het verdien model is ook een verschil. Hier is grond verhuur erg laag dus je moet in RAK in de activiteit gaan zitten. Alleen van zeehaven geld kun je je operaties niet runnen. De volumes zijn ook anders. In RAK ports zijn er 1000 aanloop schepen dus er is een minimale operaties voor de nautische diensten. Rotterdam is anders daar is meer werk. De haven is bijna 40 km lang en dus vele groter. Er zijn veel meer bewegende componenten. In RAK Ports als je de controletoren instapt zie je de hele haven en het ankergebied. Je hebt dus veel beter overzicht en dan zijn we ook de terminal operator. Dus er is weinig optimalisatie nodig ook wegens de volumes. Er is geen behoefte aan digitalisering maar wel verbetering. De coordinatie vraag tussen terminals en schepen is vele malen groter in Rotterdam door de bovenstaande genoemde redenen. Misschien wel dynamischer dan Hamburg. Omdat Rotterdam te maken heeft met meer industrieen. Bijvoorbeeld chemie en liquids heeft soms 4 locaties waar die naar toe moet in 1 haven. In Rotterdam was de afstemming altijd de uitdaging. Er was verticale communicatie, dus als er iets gebeurde dan informeerde de ene partij de volgende. Maar soms moet je een vorige partij updaten anders plant hij op oude informatie.

2. Waar liggen volgens u nog verbeteringen voor de port call?
Dat sleepers niet te hard varen bijvoorbeeld. Kleine operationele verbeteringen. Ook het gebruik van kranen.

3. Is er, in het algemeen, een noodzaak om te innoveren op het gebied van port calls?

Bij havens waar veel dynamiek is in termen van betrokken partijen, industrieën, veel data uitwisseling, groot geografisch gebied is er een noodzaak om digitale tool, zoals Optiport, te gebruiken.

5. Wat voor rol kan jullie nieuwe PCS spelen in het efficiënter laten verlopen van een port call? De PCS helpt met decision-making maar maakt geen beslissingen. Dat is een belangrijke rol van de PCS.

6. Wat voor criteria zijn van belang voor het beoordelen/implementeren van een port

call innovatie? - Bezettingsgraad van je assets
- Optimaal benutten van je assets
- Flexibiliteit van je assets
- Gelijkmatige toegang tot informatie
- Informatie deling
- User-friendliness
- Easy to use (laag dremplig)
- Reduce incidents
- Sluit goed aan op praktijk
- Effectiveness
- Reduce deviations to planning

B.2 Interview Port Hamburg

Company: HVCC
Date: 4 July 2022

1. I see that the HVCC takes a central and neutral position in the port call, what does that exactly mean?

You will understand this if you know what the port authority does and what HVCC does. The Port authority is responsible for what happens on the waterways in the port area more or less in the next 24 hours. The VTC, Vessel Traffic Center is responsible for the Safety maneuvering in the port. In the end they decided on the realized vessel sequence (vessel entering and leaving the port area). They are neutral in the sense that they do not prioritize one company's interest above the other because they shall not be understood at interfering in competition between terminals, shipping lines or other port stakeholder. By law they are not allowed to do this. They only look at safe vessel voyages in the port area.

HVCC comes in. They look forward in time (stating to collect data weeks before vessel arrival) and collaborate with the terminals, vessel shipping lines, the port authority and other stakeholder such as the pilots and tug operator to make a sequence for vessel which have relevant interactions, when maneuvering in the port. HVCC monitors several weeks in front, what are the plans for the vessel in their voyage via Hamburg. The sequence is made according to restrictions and some soft preferences of the terminals and shipping lines and suggestions of other stakeholder. This sequence is sent to the port authority for approval. They check if it's feasible in terms of only safety. Once It's all checked in terms of safety the sequence is settled. HVCC shares the full planning for the next 3 days so that everyone, who has access to the HVCC dashboards is aware of the current planning situation. Thus, HVCC provides collaboration between all major participating actors linked.

All major shipping lines, container terminals, tug companies work together with HVCC because they learned to trust the sequencing results. The VTC in the end acts based on daily requirements and can make ad-hoc changes, if needed for safety reasons. HVCC is not part of this. For the pre-preparation of sequences, the VTC trust HVCC making sound suggestions.

2. I see the partners connected to HVCC. What about the other terminals and actors? Why aren't they connected to HVCC?

HHLA and Eurogate, Hansaport, all terminals for cruise vessels are connected. Most but not all terminals are connected. 80% of the vessel calling our partner terminals have a width bigger than 25 meters and then they are relevant for detailed coordination. If they are below this, the passing restriction is not relevant and they may not require extensive coordination. Same with draught, if the vessels draft is relatively low and no passing restrictions apply, a vessel can come and go more flexible. So smaller terminals that are not linked may not have strong interdependencies with other terminals because major vessels calling these ports have no restriction due to their limited size (length and width) and draft.

Nautical service providers We receive information from pilots and we provide them relevant information. Not all linesmen are connected to us because some only serve little vessels. All tug operator companies are partners because tugs are usually needed for larger vessels and knowing the planned sequence of vessel is major input for their planning.

How do you collaborate between each other? We have tailor-made dashboards for partners with data. We provide descriptions of the suggestions we make, we have ETA, ETD some more relevant

information on the passage. We have additional talks if required via phone for detailed exchange. The dashboard serves as function that everybody has the same basic understanding of what is going to happen. It is up to the stakeholders to plan their own resources and operations.

3. How has the HVCC impacted port call efficiency? There is no quantitative data available or tracked. Since the HVCC and the nautical coordination as body to coordination arrival of bigger vessels has been implemented, everyone connected to the platform receives updates on events as soon as possible. We are connected directly to the terminal operating systems with an API, thus changes in their planning of vessel arrival and departure are mirrored in our system. We can provide this information to all partners so they can adapt their planning as efficiently as possible.

4. What Impact does the HVCC have on the performance of the organizations that are not connected? Some organization or partners benefit from the real time planning information exchange of the bigger vessels, because their operations (if it is smaller terminals and vessels) are somehow implemented and planned around the bigger vessels.

5. How does the HVCC incentivize the actors to work with HVCC?

First, we share information in a more user friendly and integrated way via one platform, for the topic of vessel coordination. Additionally, we provide interpretation of data and create value by ensuring data quality. Moreover, a data governance model is in place ensuring that sensitive data is only shared for approved connections.

We can incentive actors because when partnering with us they receive data and are to some level partner in a joined coordination process, where benefit is created directly being connected in real times as well as addressing own needs, which then can be incorporated in the sequencing, if possible. The result is bigger reliability of planning for each stakeholder in the long run including efficiency gains. At least minimum data gathering effort for every partner is reduced and own operations realized more reliable can lead in many cases to cost savings.

Trustful cooperation gained through experienced joint coordination creates win-win situations for all port stakeholders. Giving own data and receiving data from other port stakeholder turns out to improve efficient port calls. That is a finding most partners have learned over several years and don't want to miss it in the future. A vessel providing lots of data vs a vessel providing no data, can result in both going through the port call smoothly. This is because the majority is sharing data and it gives good insights already + even though some data is not exchanged with HVCC, at least all mandatory information exchange for all vessel is done at the VTC, which is exchanged with HVCC and the VTC again receives the suggestions of HVCC to integrate in the daily surveillance and realization of the actual port calls.

6. How is the arrival of a vessel planned?

The Port call appointment must be done through the terminal. The vessel agency agrees with terminal on a berthing and departure time at the terminal. The Terminal sends the berth planning to the VTC and to us usually at the same time. Because we have a shared information platform with API connections between the VTC, HVCC and the terminals. This planning is taken and fine-tuned for reflecting the interactions and restrictions thus coming up with the vessel traffic solutions as suggestions by HVCC. In Hamburg the rule, that the berth booking is the valid order for the VTC / port authority is a benefit, because this determines clear responsibilities and sources.

What happens if a vessel is very delayed?

The same as before actually, vessel traffic situations with changed inputs are updated accordingly. Sometimes if a change comes in very late the final plan has to be changed. But at some point, we stop updating and making suggestions, because than the port authority is in charge. Normally one day before execution or arrival the final plan is jointly agreed. Every change afterwards is monitored and coordinated by the VTC / port authority. HVCC is not involved anymore.

7. How does the HVCC Passage Planning work?

Along with providing sequences for vessel arrivals and departure, passage plans are given to the carrier / vessels, which tells them: when they have to be at the German bight, their ETB at the terminal or pilot stations, their suggested travel speed and some more. Outbound carriers receive suggestions when the optimal departure time would be to leave the port as fluent as possible. If there are changes required because the situation changed, the sequence is updated and updated passage plans are sent out.

Major criteria is to enable the maximum number of vessel to leave and enter the port as fluent as possible under the given restrictions.

8. What is the biggest bottleneck of the port call in your port? What makes it difficult

to optimize the port call?
We have a 100 km approach up the river Elbe, which is a tidal river. On the river we have a passing restriction meaning that vessels with a summarized width of +90 m meters cannot pass each other. The water levels influence the planning. The draughts of the vessel also plays a role in planning the port call, due to the tidal restrictions on the river Elbe. Some vessels need to leave and enter the port with the flood wave. The tug and pilot availability are in general not a big constraint in HH.
9. How are incoming and departing vessels served? Who gets priority? First-come first serve?
We try to maximize the vessels coming in and out. It is never first-come first serve. We help the vessels in such a way that the time deviated from the original arrival time agreed between the terminal and the shipping lines or vessel is minimized.
10. Why does the HVCC work in your port? Does the organizational structure of the port of Hamburg influence the efficiency of the port call? The Port Authority must agree to the suggestion and work done by HVCC. This legitimation is necessary. With the major container terminals as our shareholders, the connection to relevant terminals is strong and important.
Do your partners show a resistance in sharing information?
The parties like tugs, pilots and linesmen and some terminals and shipping lines are in competition with each other thus they tend to share some data reluctantly. Major finding is, that sensitive data (described by each individual party is not shared) Public data is the minimum information they would normally share with the port authority. We have data governance policies that makes sure only data is shared with the companies that give permission to share. However, our partners see that the more they share the better the planning can become for them. To be more precise: we only receive and share data around the port call of the vessel (ETA; ETD; drafts,…), no contract information, no cargo data, and so on, because this data is sensitive and right from the start not in our system.
11. Is the size of the port dependent on the ability to optimize the port? How? I think it is the whole situation of the port. We have quite some nautical restrictions in the port which forced us to produce an improved joined coordination to ensure the accessibility of the port and the service to the vessels. Need for efficient coordination was high. The more vessels and the more stakeholders are connected and dependent on each other's planning the more complex a port call becomes. Changes of on parties planning can affect other parties. The more interdependent the port stakeholder and the respective vessel port calls are the more beneficial or important a port call coordination can be. The bigger the network the more important it becomes. Still in a less complex port a coordination center can help you because all the administrative tasks are reduced via a centralized data exchange platform.
12. During a port call, what are important objectives according to HVCC? Safety, Minimize delay of vessels, Time deviation of original plans,
Reliability of suggested plans Amount of unsolved conflicts, which couldn't solved in the joined coordination and needed overruling of the port authority to determine the vessel traffic sequencing
Port Call Efficiency

B.3 Interviews Port Antwerp-Bruges

B.3.1. PA Port Development

Date: 27 June 2022
1. Is oke om deze sessie op te nemen? Ja dat is goed als het beeld maar niet verspreid wordt.
2. Wie is er verantwoordelijk voor de planning van de port call? Aanloop is vrij complex omdat de aanloop vrij lang is en deels op Nederlands en deels op Vlaams gebied betreft. Geen bevoegdheid over de Wester scheldt of op zee. Verdrag in 2005 zijn afspraken gemaakt over hoe partijen samenwerken. Er zijn twee ankergebied, Steenbank voor is nederlands loodzen en de Oostende is voor de vlaamse loodzen. Voor het verkeer naar antwerpen zit er een verdeling op. Dit betekend dat 27,5% door nederlandse en 72,5% door vlaamse loodzen wordt gedaan. Dit is een extra complexiteit in de planning. Totale tijd duurt zon 6 tot 9 uur. Dus de planning zit ver vooruit. Sleepers hebben adhoc planning. Afhankelijk van de schip, weer, ect. Eerste contact moment is 2 uur voor aanvang van pilot boarding place. In Antwerpen werken we met drie loodzen. Dus we hebben een zee loods, rivierloods, en dokloods. Er zijn dus drie wissel momenten. Dit maakt het plannen ook complex. Waarom is dat? Gewoonte, Vlaamse loodzen vinden dat beter. Komt ook door verschil interne regelingen van

corpsen in termen van werktijden, verloningen ect. Daarom is er geen incentive om samen te gaan. De haven maakt een verkeersplanning over tijden van binnen lating. Antwerp Coordination Center (ACC) is verantwoordelijk voor coordineren van de nautische diensten en het efficient plannen van het haven verkeer. Ze maken de basis planning. De basisplanning wordt gedeeld met de partijen in de haven en door een iteratief proces wordt de planning vastgesteld.

3. Wat is jullie rol in het efficient laten verlopen van de port call? In hoevere hebben jullie invloed op het verloop van de port call? Het ACC staat in het midden van het proces. Wij krijgen ETAs binnen van schepen en gaan daarmee, aan de hand van de capaciteiten plannen. verder krijgen we van de nautische partijen binnen wat haalbaar is, wat de constraints zijn, en wat de terminal voor planning heeft. Met deze informatie gaat het ACC een haven planning maken die haalbaar is voor iedereen. Zo ben je iteratief een planning aan het maken die voor iedereen past. Op het ACC zit een verantwoordelijke van de Vlaamse loods om te zorgen dat de planning realistisch zijn en veilig gaan. Dus er is een fysieke component van mensen met expertise en er is een digitale component waar alle informatie samen komt en data up-to-date hoort te zijn.

4. Wat is de grootste moeilijkheid/knelpunt in de port call? De sluizen en de getijen in de haven maken het lastig te plannen. Sommige terminals zijn achter de sluizen en sommige voor. Sommige schepen zijn tij gebonden dus zijn er vensters voor die schepen. We hebben veel tankers (bulk schepen) achter de sluizen die veel transfers maken naar diverse terminals daardoor hebben ze een kortere horizon tussen Request en Actual time of depature. Loods tekorten van de vlaamse loodswezen is vaak een probleem. Ze kunnen op korte termijn nog afzeggen. Het is dus meer een voorspelbaarheid probleem. Verder draaien sluizen niet altijd heel nauwkeurig. Vertragingen in of rondom sluizen kunnen makkelijk onstaan. Dus erg strak plannen is niet mogelijk. Bulk cargo kan vaker uitlopen en heeft vaker vertragingen (ivm extra samples, terminal vertraging) dan container wat het dus moeilijker te plannen maakt. Bulk goed is minder voorspelbaar. Het feit dat sleepdiensten meer ad hoc plannen en dus korter vooraf, maakt het maken van een haven planning ook lastig. Wij baseren onze planningen op een beschikbaarheid van 8 uur vooruit.

5. Met welke volgorde wordt binnenkomende schepen geholpen? Volgorde van schepen is meestal first-come first-serve, tenzij er een tij gebonden schip is. Die wil je niet laten wachten want dat kan betekenen dat die 12 uur moet wachten en daar wordt niemand blij van. Brabo is het concessionaris van het haven bedrijf die de dok loodzing en vast make van schepen doen.

6. Hoe is jullie relatie met de terminals? In hoeverre hebben jullie invloed op de planning van de terminals? Wij krijgen van terminals vragen door om schepen op een bepaalde tijd binnen te hebben. Op basis van die informatie gaan wij kijken wat de capaciteit is van de sluizen en getijen. De shipping agencies hebben contact met terminals. Dus als de ACC planning veranderd (en dus die van de terminal) is het aan de terminal dit door te geven aan de vessel agency. Het ACC kan dus wel zeggen dat een schip bij een terminal iets later gaat aankomen als eerst een getijde schip moet binnenkomen. Maar de terminal weet dit dan 8 uur van te voren en kan dan hun diensten erop aanpassen.

7. Wat is het grote verschil tussen de nautische diensten voor de sluizen en na de sluizen? Welke kant werkt efficiënter(minder vertragingen)? Hoe komt dat? Na de sluis is ons eigen sleep bedrijf. Wij hebben veel zicht op de planningen en hebben ook veel zicht op de oorzaken van problemen. Op de rivier zijn het private partijen. Daar hebben we minder zicht op de drivers van de problemen. Al in al minder transparantie dan onze eigen sleepers. Dit maakt het veel moeilijker om mee samen te werken omdat je niet altijd goed inzicht hebt over de beschikbaarheid.

Waarom zijn partijen terughoudend in het delen van informatie? Ik denk dat geen enkele partij wil laten merken dat ze geen perfect goede service hebben. Bedrijven tonen hun imperfecties liever niet wegens angst voor slecht imago. Ze worden er niet op beboet. Er is wel een sleep voordering met een minimale service. Wordt niet altijd gehaald. Hier zit ook een nuance verschil in hoe dit gemeten wordt. Er staan geen sancties op het niet behalen van de voorderingen. Het enige wat kan gebeuren is het intrekken van vergunning. Maar dit gebeurt niet want er is een capaciteit probleem.

8. Onder welke contracten werken de nautische diensten? Zijn de nautische diensten bang om hun positie te verliezen? Zijn nautische diensten daardoor meer terughoudend om samen te werken? Vrije markt partijen. Er zijn bepaalde maatregelen waar een sleeppartij aan moet voldoen om een vergunning te krijgen. Dit is in lijn met Europese regelgeving. Als je aan de voorwaarde voldoet krijg je een vergunning en mag je slepen. In de realiteit is er ruimte voor een bepaald aantal spelers in de markt. Dus wordt je als partij niet heel snel bedreigd door concurrentie als er geen groot marktaandeel beschikbaar is.

9. Wordt er informatie gedeeld tussen de betrokken actoren? CBS – Central broker system. Ze geven wel aan of sleepboten beschikbaar zijn of niet alleen geven ze geen reden. Waardoor je over een uurtje het weer moet vragen. Meer informatie zou tot betere inzichten kunnen zorgen waardoor er beter gepland kan worden.
10. Wie bepaald hoeveel sleepboten er nodig zijn per schip?
Een vessel agencies vraagt dat zelf aan maar schakelt ook met de ACC om advies te vragen over hoeveel sleepboten ze nodig hebben.
11. Heeft de grootte van de haven invloed op de mogelijkheid om de haven te optimaliseren? Nee niet zoveel invloed.
12. Zijn er andere context factoren die invloed kunnen hebben op port call optimalisatie?
Vooral de tijds horizon is belangrijk voor het optimaliseren van een port call. En hoe lang de aanloop is, hoe langer de aanloop hoe meer complexiteit en hoe meer er kan veranderen. Voor ons is het een bijzonder geval van aan de ene kant prive partijen en aan de andere publieke partijen. Samenwerking is anders want bij privé loodswezen gaat het om optimaal laten verlopen en zo veel mogelijk schepen helpen. Maar bij de publieke loodswezen zijn er meer publieke belangen. Veel sterke werking van vakbonden en beroepsorganisatie die waken over balance werk en prive. De motivaties en belangen zijn anders in deze havens en dat maakt samenwerking moeilijk.
13. Wat zijn jullie KPI's voor het verloop van de port call? Voor de gehele keten geen kpi waar we het over eens zijn.
Kosten, Efficiëntie , Delays, Afwijkingen, Safety, Sustainablility – voorzichtig mee bezig maar gaat nog eventjes duren.
14. Wat zou volgens jou een goede oplossing zijn om de port call efficiënter te laten verlopen? Wat moet er veranderen? Nog transparanter informatie willen delen van alle kanten. Voornamelijk het delen van redenen waarom er geen capaciteit is. Bijvoorbeeld we hebben van deze categorie geen zee-loodzen meer maar van andere nog wel. Dan zou je kunnen schuiven met je planning. Nog een voorbeeld: er moet geslapen worden van dan tot dan.
Wat heeft u daar voor nodig? Gewoon gesprekken die nu ook al lopen met partijen om informatie te delen. Er zijn al gesprekken bezig en er zijn al verbeteringen.
Waarom is de bereidheid er niet om transparanter te zijn? Tja moeilijk, men is voorzichtig met informatie delen omdat ze niet de aangewezen partij willen zijn. Te veel een 'blame and shame' mentaliteit. Andere de schuld te geven. Vroeg of laat loop je altijd tegen capaciteit problemen aan en dat is niet erg. Maar er is wel schrik dat er vroeg of laat een gesprek komt dat er capaciteit bij moet komen.
15. Wie zou verantwoordelijk zijn voor haven optimalisatie? Wat we nu al doen is met gezamenlijk verkeers management aan tafel gaan om meer vertrouwen te krijgen in elkaar. Dat is een proces dat tijd kost. Vertrouwen winnen is lastig de laatste tijd en dat is een traag process.

B.3.2. Terminal Operational Manager

Date: 19 July 2022
1. Wat zijn de afspraken met rederijen en sleepers? Als terminal hebben wij geen contract met sleepdiensten. Het begint eigenlijk met de rederij en de sleep dienst. Rederijen die op schema varen hebben vaak wel afspraken met een sleepdienst. Die spreken een tarief af met elkaar. De kapitein bepaald uiteindelijk wel het aantal slepers. Dit zijn er meestal twee. Als er slechte weersomstandigheden zijn dan 3. Onze rol hier tussen is niets.

2. Wat voor rol hebben jullie in het binnen halen en vertrek van een zeeschip?
Wij zijn onderliggend. Dus wij kunnen geen invloed uitoefenen op de ketenwerking. Wij zijn voornamelijk in contact met de agent van een schip om afspraken te maken.

3. Hoe plannen jullie een port call van een schip?
Het begint bij ons met een aanvraag van een rederij. Wij kijken dan voornamelijk naar hoeveel bewegingen er gedaan moet worden voor het lossen en laden. Dan kijken we naar de tij vensters. Wat is het vroegst mogelijk uur dat het schip aan kant kan liggen. Dan wordt er gekeken naar ploegen beschikbaarheid. Dan wordt er een ETA gezet. De vertrekkers hebben altijd voorgang. Dus die willen we zo vroeg mogelijk klaar hebben zodat de volgende met een tussen tijd van 2 uur kan arriveren.

Waarom 2 uur?
Dat is de minimum veilig range tussen vertrekkend en aankomend schip zodat, een aankomend schip bij Vlissingen eventueel nog omgekeerd kan worden. Dit is de regel die we volgens de keten van Antwerpen hanteren.

Dus wij wijzen ligplaatsen toe aan schepen en dan kan de haven autoriteit samen met de keten dit goed opvolgen.

4. Hoe wordt deze planning gedeeld? Met wat voor partijen?
Met het scheepsvaart management. Dat is het coördinatiecenter. Die helpen met de traffic coördinatie en de bestelling van de loodsen. Eigenlijk is er een samenwerking tussen de loodsen, de haven autoriteit, brabo en de slepers om de keten te regelen. Hier is een centrale tool voor: APICS Systeem, hier kunnen verschillende keten diensten in besteld worden. Verder hebben wij ook nog de site van de loodswezen (LIS) waarin wij kunnen zien of en wanneer een schip beloodst is. Zo kunnen wij ook onze inschattingen maken.

De voornamelijk samenwerkingen ligt tussen de agent en de haven autoriteit.

5. Wat is volgens uw de knelpunt in het haven aanloop proces van Antwerpen?
Voor ons is een pijnpunt als er meerdere vertrekkende en aankomende schepen tegelijkertijd geholpen moeten worden. Zeker als die schepen dezelfde slepers delen omdat de rederijen contracten heeft met die sleepdiensten. Dan is er meestal vertraging in het vertrek van schepen wegens gebrek aan slepers. Dan moet een schip langer aan wal blijven.

Ten tweede is het getij een knelpunt. De diepere schepen moeten dan voorgang krijgen. Dus hier is ook genoeg capaciteit voor nodig. Vaak zijn er tijdens piekmomenten te weinig slepers. Ook is het zo dat de haven een lange aanloop heeft waardoor het soms lang kan duren voordat een extra sleepdienst aanwezig is van een andere haven. Bvb: Hansweert - Terneuzen

Coördineren jullie je planning met de andere terminals?
Nee dat doen wij niet zelf maar de haven autoriteit doet dat wel. In APICS heb je inzicht in welke schepen op welke terminals gemeerd zijn.

6. Is er een noodzaak om efficiënter de haven aanloop in te delen?
Er zijn tools die Antwerpen naan het ontwikkelen zijn binnen APICS zodat je flows beter kan volgen. Dit is nu alleen inzichtelijk voor de agenten. Maar wij hebben momenteel daar no geen toegang toe.

7. Is er een vorm van samenwerking met de andere terminals? Zou meer data deling leiden tot efficiëntere haven aanloop proces?
Niet perse denk ik. Iedere terminals werkt een beetje in zijn eigen winkel, doet dingen op hun eigen manier.

8. Hoe wordt de volgorde van schepen bepaald als er twee schepen van verschillende terminals tegelijk binnen komen?
Dit is een proces wat tussen de scheepsagent en het coördinatie centrum ligt. Als er verwachte vertragingen zijn dan horen wij dat via de scheepsagent wel. Die band is nauw.

9. Heeft de concurrentie tussen terminals in havens invloed op het haven aanloop proces?
Er is niet heel veel concurrentie omdat PSA de grootste is in Antwerpen op de rivier. Wel heb je achter de sluizen andere terminals maar daar is de traffic minder. Daar heb je meer tankers en dat is een andere manier van werken. Verschil tussen bunkers en containers. Containers varen graag op JIT en Depature as soon as possible. Een schip is gemaakt om te varen en niet aan de kant te liggen.

10. Wat zijn volgens uw belangrijke criteria tijdens het haven aanloop proces? Waarom?

- On time arrival
- Aansluiting op shift diensten.
- Inzet van ploegen
- Turn-around time berth
- Uitwisseling uitgaande en binnengaande
- Goede coördinatie

- Keten capaciteit
- Veiligheid – afmeer afstand

B.3.3. Pilots Operational manager

Date: 14 July 2022

1. Wat voor rol hebben jullie in het binnen halen en vertrek van een zeeschip?
De haven heeft de regie. Stel er zijn twee schepen en 1 loods dan bepaalt de haven welke er geholpen wordt.

2. Hoe verloopt het proces voor het binnenhalen van een schip?
Afhankelijk van waar het schip vandaan komt (Noord of West) is het of 21 mijl of 34 mijl tot Vlissingen en dan moet het nog naar Antwerpen. En dat is ook nog eens 36 mijl. Dus dat duurt uurtje of 6 a 7. Bij Vlissingen is er meestal een loods wissel.

Er is een gezamenlijke werkvloer in Antwerpen voor de keten. In de haven is de haven autoriteit de bevoegde autoriteit maar op de rivier is dat de GNA. We kijken allemaal in dezelfde systemen.

3. Hoe plannen jullie de loodsen voor de haven van Antwerpen? Zijn jullie daar zelf verantwoordelijk voor?
Ja dat doen we zelf. De haven geeft bijvoorbeeld aan wanneer een schip aan wal moet liggen en dan regelen wij dat er tijdig dat er een loods is. Wij hebben een predictie model waarin wij alle relevante factoren mee nemen om het reisplan te maken. Dus wij kunnen goed terug rekenen wanneer en hoe de planning eruit ziet. Die reisplan delen wij met de andere keten partijen. Dat is het spoorboekje voor de reis van een schip van zee tot ligplaats of andersom.

Als een loods aan boord stapt dan kan het reisplan geüpdatet worden met een nieuwe ETA die de loods aan boord geeft. Als dit meer dan 15 min afwijkt dan komt er een melding voor alle partijen. Het aantal slepers wordt in de reis planning vooraf door de sleepdienst ingeschat. Kan nog veranderd worden als de loods ism de kapitein het onveilig vindt en anders beslist. Het predictie model geeft ook een goed beeld hoelang een reis gaat duren voor de slepers.

Leidt een zo'n predictie model tot een efficiëntere haven proces?
Zeker want vroeger werd er uitgegaan van een gemiddelde reis tijd over de schelde waardoor je vaak of te vroeg of te laat aankwam. Zo benut je je capaciteit van alle ketenpartners ook niet efficiënt. Met ons predictie model meten wij ook de inefficiënties om er van te leren. Zo kunnen we de keten verder optimaliseren.

4. Wat is volgens uw de knelpunt in het haven aanloop proces van Antwerpen?
Er zijn altijd piek momenten met verschillende oorzaken. De slepers kunnen het druk hebben maar andere partijen ook. Verbeterpunten zijn er altijd. We zien dat met de terminals bijvoorbeeld in de ploegenwissel. De piekmomenten in havens zijn tijdens de ploeg wissels. Maar wij als nautische diensten willen de piekmomenten afvlakken maar voor de terminals is dat lastiger en duurder. Maar als de piekmomenten een gegeven zijn dan kunnen wij daar zo efficiënt mogelijk mee omgaan.

Hoe is de samenwerking met de Terminals?
Daar spreken we af en toe mee maar gaat niet over het verspreiden van de piekmomenten. De haven die vraagt en de nautische diensten die draaien.

5. Delen jullie ook informatie met andere partijen in de haven? Hoe wordt er informatie met jullie gedeeld?
Er is een centrale computer systeem (Central Broker System, CBS) waar iedere keten partij aan gesloten is. Via dit systeem wordt er gecommuniceerd. De haven is leidend omdat die contact heeft met de agent en de terminal.

6. Wat zijn de barrières tegen delen van informatie? Zouden jullie bereid zijn om data te delen met de nautische diensten als jullie eigen operaties er ook op vooruit gaan?

Wij zijn zeker bereid data te delen. Dat komt door de no blame and shame afspraken. We vinden het niet erg als er een reden staat waarom we niet kunnen leveren. Daar kunnen we juist van leren.. In Antwerpen is er een een sleepvoordering. Daarin staat een minimale sleepcapaciteit in om te mogen slepen in Antwerpen. Uitwissel moet mogelijk zijn.

7. Hoe is de samenwerking met de PA en keten partijen?
Vrij goed. We zijn ook genoodzaakt om samen te werken door de complexiteit van de lange aanvaar route. Door de drukte op de rivier is samenwerking ook voor veiligheid en efficiëntie genoodzaakt. Niemand krijgt de factuur van zijn fouten. Het gaat om vertrouwen en verbetering. Verder hebben we afgesproken om een no blame and shame cultuur op te starten met elkaar.

8. Er zijn verschillende loodsen organisaties. Hoe verschillen jullie in organisatie van elkaar?

De Vlaamseloodsen doen 72.5% van alle schepen van en naar Antwerpen en Gent en die zijn iets anders georganiseerd. De Nederlandse loodsen zijn multivalent (dwz bevoegd op zee en op de rivier) en bedienen de overige 27,5%. De Vlaamse loodsen zijn verdeeld in 3 categorieën: zee, rivier, kanaal. Voor een ship maakt het niet uit. Voor de keten scheelt het 10 min tijd voor een loods wissel op Vlissingen Rede.

De verdeling wordt automatisch gedaan. Wij delen hetzelfde beloodsing systeem en beloodsingsmiddelen met de Vlaamse loodsen. Een loods bestelling moet ruim op voorhand worden ingegeven zodat we er bij de planning rekening mee kunnen houden en het schip tijdig van een loods kunnen voorzien.

Loodsen organisatie hebben andere bedrijfscultuur. Heeft dit denk je invloed op het totale aanloop proces?
Nee, onze expertise is hetzelfde als de Vlaamse loodsen, alleen de interne werkafspraken en inzetregels zijn verschillend.

9. Zou uw de relatie met de andere loodsen beschrijven als competitief of coöperatief?

We hebben goede samenwerking met de Vlaamse loodsen.

10. Wat voor factoren hebben invloed op het efficiënt laten verlopen van een haven aanloop proces?

Er zijn verschillende opvaart types ETA en GTA; een agent kan aangeven welke tijd die aan de kade wil liggen, dat heet dus GTA (Gewenste Tijd van Aankomst aan de ligplaats). De tweede optie, ETA (Estimated Time of Arrival op het loodsstation op zee), is wanneer die bij de loodsstation is. Dat eerste is voor ons makkelijker omdat wij dan terug rekenen in planning. De tweede optie is lastiger omdat je niet zeker weet of de keten dan klaar voor is. Ook voor de agent is het moeilijk om te weten wanneer het schip aan kade gaat liggen.

In Antwerpen hebben wij een planning horizon van 8 uur op voorhand, dat heeft de haven bepaald. In Rotterdam is het 2 uur.

Vertrouwen en transparantie zijn belangrijke factoren. Wij hebben te maken met meerdere bevoegde partijen, GNA bestaat uit Vlaamse en Nederlandse bevoegdheden, dan de haven autoriteit zelf. We zitten met meerdere partijen aan tafel. Dus dan zijn we eerder gedwongen om goede afspraken te maken.

Wat ook moeilijk is in Antwerpen is dat je twee verschillende loodsstations op zee hebt, te weten de Wandelaar en de Steenbank. In Rotterdam is er maar 1.

11. Wat zijn belangrijke criteria voor jullie tijdens het haven aanloop proces? - Tijd aan boord

- Capaciteit
- Vertraging van een schip
- Wachttijden
- Tijdig data beschikbaarheid
- Betrouwbare data deling
- Efficiency – Betere inzet van middelen
- Veiligheid

B.4 Interview Port Arthur

B.4.1. Tugs Commercial manager

Date: 27 June 2022

Discussion about Data Sharing There is certain information that you don't want to share with your clients or competitors. For example a engine blows up due to bad maintenance or a boatmen crashes due to bad training or experience or there is a Covid outbreak. All in all you don't want to reveal your vulnerability to the outside world. "but I guess for port call optimization you don't need to know the causes. You only need to know the availability, Is this tug available and capable to do this job from then to then, yes or no?".

1. Is it oke to record this session? YES Actors: Two port authorities, Beaumont and Port Arthur they compete with each other. All Terminals are privately owned. Tugs are private companies. Pilots are for the whole waterways. They are ZZPers The pilots give orders to the pilots. Because the Pilots are ZZPers they can determine their own rules. So in theory, the requirements can change according to whom ever the pilot is. In practice this doesn't happen that much.

2. What are your responsibilities to efficiently berth arriving and departing vessels? Depends on the port. We have a dispatch office for every port and they are responsible for allocating the resources according to demand. Traffic schedule is set by others. In port Arthur there is no harbour master and the pilots act as the harbour master. So they will tell us where and when they need availability. And the dispatcher office is responsible for responding to the request as best as possible. Now we have augmented our dispachers with Optiport to optimize the tug scheduling.

3. What do you consider to be the bottleneck within the port call (no internal issues)? Is there a need to improve the port call? Yeh I think the more complex a port is the more the need for collaboration and communication. The difficulties in this port are geography, the port is 50 miles long with terminals very spread out along the river. You have demand for tugs in many areas. So the demand profile in a geographical diverse port system is one inherent issue. Secondly, You have traffic issues which the pilots put in place. For example the day light restrictions for the larger sized vessels. The cannel is daylight restricted because it's quite narrow. So the pilots want to give priority to the larger sized vessels that are daylight restricted because of the time restriction and more revenue for the nautical service providers. Because of the 6 vessel convoy all tugs are taken an no other activity can be performed.

The customer will say we need more tugs. But nobody want to pay for that. And if we add 2 tugs then the convoy will simply increase to 7 vessels and the same problem will be present. So there is a lot of waiting for the small vessels and there are a lot of inefficiencies. That's why there is a need for Optiport. We have done Optiport to be relatively as efficient as possible. So now the next step is enhanced collaboration with the port system in stead of building more tugs.

4. With what time horizons do you guys work? When do you receive a job? From who do you receive this? We get a dispatching list from the pilots with all the vessels and what times they will be coming in to get a rough outline. We have a chatbox to instant message the pilots which has actual orders from pilots that say we need 2 tugs. The dispatcher plans the tugs in. if no capacity we ask the competition to help us out. We require 4 hours in advance notice and usually get it sometimes not. Sometimes the pilot is not onboard yet.

How do you see collaboration enhancing the efficiency of the port call? There are 3 dispatching offices and they are all 3 communicating to dipach their respources as efficiently as they can. But they are sitting in different offices and communicating with each other in a trianglur way with different modes of communication. That is in my mind inefficient. Maybe it's not. Maybe the gain of bringing them together is not that significant. Now a second way to improve the port call could be to

geographically restrict tugs to a certain location of the port. So that there is activity for the port area that is not daylight restricted. Because the non-daylight restricted vessels and terminals feel like their being left out and they have to wait a lot. The idea is to have maybe 10 tugs for the entire port and restrict 2 tugs for port Arthur.
Why aren't they doing that yet? The pilots don't want to do that. This was a year or 2 ago. Maybe it's different.
6. What influence does the terminal and port planning have on your planning? The terminals and shipping agencies are very important to us because they are our customers however we don't get jobs from them we get them from the pilots. So the pilots determine the planning of the port.
8. How is your organization contracted within the port (Free market, Concession, licensed)? How does this effect how you schedule/operate your processes? Free market
Are you afraid of competition? Yes we are always afraid of competition. But from a business point of view you cant operate two tugs. You need more contracts.

11. What other port content factors could have a positive or negative influence on the your processes? Weather does not impact our operations that much because it's quite protected. Some parts of the ports are daylight restricted. That means some vessels are helped in convoy of 6 vessels. That means there are 12 tugs necessary to assist this convoy and that is full capacity. The convoy can take about 6 hours.
Identifying Objectives
12. What level of freedom do you have in determining your own KPIs, goals, objectives? There is no influence from outside the company about our KPIs. There is no requirements or expectations from others. No KPIs are reviewed by the PA for example. Internally we do look at KPIs a lot.
13. For your company, when performing activities for the port call, what are your companies objectives in terms of efficiency?
KPIs Port call:

- Out of service time
- Lost time
- Injuries
- Near miss reports
- Delays
- Manning issues
- Different types of out of service
- Tug utility Commercial KPIs
- Volume of jobs
- Engine hours
- Revenue per job
- Fuel consumption

Categories of KPIs: Safety, operational efficiency (costs), availability, utilization.
What about sustainability? The market is not at a point where they are willing to pay for more sustainable solutions. It's still very much about whats the price?
14. What would you consider to be a good solution for improving the port call? I think more transparency and more collaboration would help improve the port call in port Arthur. You have data silos that prevent understanding the full picture. It is efficient but it is also a very human driven. The system is thus complex in a matter that computers could often do a better job in planning. A marginal improvement can happen if planners sit in one room. But ultimately the big leap would come from a system that can plan the port!
Why is it not possible to implement such a system tomorrow? I don't think that parties are open to that. Why not? Difficult… people are afraid of change. People like control.

B.4.2. Tugs Director of operations

Date: 20 June 2022
- No notes from this interview because the information was similar the the interview above.

B.4.3. Pilots Operational Manager

Date: 22 July 2022

The Sabine Pilots have moved about 6400 vessels in the last 365 days.55miles of total waterway serving 40-50 terminals both public and private. The outer 20 miles of channel is 800 feet wide, the middle 10 miles are 500 feet wide and the inner 25 miles are 400' wide.

1. What is the process of requesting a berth in the port?

The agent organizes the request for a berth with the terminal. We have 40-50 different terminals. Agent makes all the arrangements for the terminals, tugs, pilots, line handling. He calls our dispatcher 48 to 72 hours prior to the port call to set order for a vessel movement. The dispatcher will then include it in the planning.

2. As what role do you see yourself in berthing a vessel?

Our dispatchers are more or less the harbour master. It has been like this since 1881. There is no governmental harbor master in our port. Three public terminals and the rest are private. We try to move day light restricted vessels and non-daylight restricted vessels as efficiently as possible.

3. How do you guys determine the sequence of incoming vessels?

We schedule the vessels of each wave of inbound or outbound traffic based on the distance to the destination with the vessels that have the furthest to transit going first. In our channel vessels are restricted to one-way traffic (no passing or overtaking when the combined beam of the two vessels is equal to or greater than ½ the width of the channel. These are mostly modern vessels with 32.2 meter (106 feet) beam or greater. We look at operational restrictions on first come-first serve basis and do not prioritize based on commercial arrangements.

4. How do you guys coordinate in terms of information sharing with other nautical service providers?

Sabine Pilots Web service Vessel Traffic Online. It shows all the inbound and outbound vessels with ETAs. Our dispatchers are constantly on the phone with vessel agencies. The vessel traffic online website is real-time. The agents, the tugs operators, the terminals, linesmen have access to it. For communication with the tugs, teams chat box and telephone are used.

5. Do you guys have a port community system?

The vessel traffic website of the pilots can be seen as a port community system.

6. How would you describe the relation with the other organizations in a port call?

We have good communication with all the parties. We have frequent meetings with each other to see where we can improve on. Safety as well. For example, after a shutdown a terminal can give a priority list and we will keep these things in mind when scheduling the first recovery waves of traffic. **7. What is the main bottleneck in the port call process?**

We need a wider channel. We could also use more tugs. In the last 10 years we have almost doubled in pilots. The tugs definitely haven't doubled. There are periods ships are waiting on tugs. You might get a 2 to 3 hour wait. Some tugs are crewed only to 12 hours so then they would have to wait. Linemen have labor shortage problems sometimes. This is because it is a low paying job.

8. How would you improve the port call if you could?

Aligning the outbound and inbound crew. The outbound vessels have to pass a certain point before the inbound vessel can be assigned.

Use of helicopters could also help the port call. **9. What criteria are important to you when valuing an innovation for the port call process?**

Requirements for an improvement measure

- It would have to work
- Reliable
- Smart
- Less waiting time on vessels
- Safety
- Efficiency – move as many ships a day as possible
- Amount of vessels
- Rest time
- Pilot hours
- Close calls

B.5 Port Sydney

B.5.1. PA Harbour Master

Date: 19 July 2022

1. Is it oke to record this session? YES

2. What is the role of your port authority to efficiently berth a vessel? Who is responsible for planning the port call?

We provide the VTS service, we provide the marine pilots, other services like tugs and lines are being monitored to see if they can do a job. So the port authority takes a coordination role in moving vessels in a safe manner according to the restrictions. The VTS doesn't take any commercial factors into account. The terminals coordinate with the vessel agencies about what slots are occupied by what vessels and then they get put into the PCS. Once it is in the PCS the tugs and linesmen get the job. If the job is not possible due to weather and safety conditions then the VTS coordinates the alternatives with the vessel agent. The tugs also provide their capacity problems through the PCS if it is needed. Typically we have 60 hours upfront planning. Minimum requirement is a two hour notice. But with two hours it is really difficult to service. I think 4 to 6 should be a minimum to have services available.

3. Is there a need to improve the port call? What do you consider to be the bottleneck of the port call?

At the moment based on the amount of ships we are moving out of the port of Sydney and botany, we don't have defining factors in terms of capacity. We can handle more vessels. The efficiency of the waterside is not a problematic factor at this moment. No big problems on the waterside. At least not things that cannot be sorted by better communication.

4. Why are the pilots working for the port authority and why aren't more services provided by the port authority?

It's written into our legislation here. Tug operations is a licensed activity. There are two entities that hold a license. So we formally manage them in terms of performance but we don't manage their staff for example.

Do you notice a difference in performance due to the way they are licensed? Not really. End of the day it comes down to communication issues. Our port community system works quite well and is transparent. So the external entities are quite aware of what is happening and what needs to happen.

5. The port call of port Hedland is very structured. In port Sydney the actors act more individually and the port call is less efficient. Why are there differences between ports in terms of port call efficiency?

In port Hedland the order vessels being served is written in commercial documents. That goes back to the capacity of the big miners. That is berths, volumes handled ect. The commercial agreement is thus in line with the capacities of what the terminals can offer. There are guidelines and protocols that determine how the vessel are moved in port Hedland. This means that the organization of a port call is very structured. The pilots don't work for port authority in port Hedland but they are contracted under the port authority. But they work in a very similar way. So no real difference between contracted pilots and port authority pilots.

7. In what order are the vessels served?

The terminals tells us which ships they want. So the terminals determine what ships they want in what order. Then it goes into system and the nautical services react accordingly. But the commercial discussion on who gets what slot is determined by the terminals.

8. Under what contract type are the nautical services providers operational in the port? (Licensed, concession, free market)

Tugs and linesmen are licensed in the port and the pilots fall under the port authority. **9. What other port content factors could have a positive or negative influence on the your processes?**

Coordination is one. The other is the ability to use data to show performances of other, Tugs, pilots, also terminals. On-time performance, delay performance. So the PCS needs to be able to show these data points to show how the port is performing. But you need to do this for the whole supply chain. Having a structured and good PCS is important for the port.

10. What level of freedom do you have in determining your own KPIs, goals, objectives? It is determined by us. We are able to set our own strategic objectives.

1**1. For the PA, when performing activities for the port call, what are your companies objectives?** Broadly speaking it is safe and efficient operations. You want activities to by on time and handled safely.
- Costs is not really my department, it is something set more by government.
- % of time a pilot serves a ship
- On time arrival tugs
- Servicing as scheduled
- Max. Dangerous incident

12. What would be a good solution to improve the port call? Why is that solution not yet implemented?
Could be a range of things. More soft approaches like improving the port management system. It is also possible to have more hard approaches like investing in infrastructure. It also depends on the congestion level/type in a port. In terms of peak congestion it is never one solution but a combination of factors; infrastructure, software, communication, better planning. The solution must be tailored to the problem.

B.5.2. Tugs Commercial Manager
Date: 28 July 2022

1. How do you guys efficiently plan the berth a vessel? Who is responsible for planning the port call? How and what information is shared with the port authority?
The PA uses a system called SHIPS, it is the central system for booking marine services. Service providers will monitor that platform and we will do our scheduling around that platform. It is real-time and accurate data. It is one point where all the stakeholders go to. Tugs don't need to provide information we only take information from this platform. Tugs only have to confirm the jobs.
2. Is there a need to improve the port call? What do you consider to be the bottleneck of the port call?
In general no. After a weather event there can be some congestion. If it happens it is solved within 1 or 2 days. The few nautical limitations we have the faster we can get back on track with a schedule. The tidal effects are not huge here in Sydney.

There are few restriction in ports, are there any factors making asset allocation of your tug difficult?
Only when the weather changes, more tugs are required then it becomes more difficult. Otherwise the table descriptions are quite accurate on how many tugs are needed.

3. Do you believe that more collaboration could improve the efficiency of the port call process?

There is good dialogue between the agents, terminals, ports and ships. This is usually done by phone calls. But the changes in times are usually communicated well. Tugs operators are operating on contracts with terminals. This leads to inefficient port calls I would say because a when a tug operator has down time then there is no activity performed and the vessels are being pushed back in schedule. The vessels have to wait for a long time. Jobs aren't given away due to the very low margins.

5. You are licensed under the port authority. What kind of requirements do you have to meet?
On time performance is a requirement set by the PA and we have to react within 15 minutes in case of emergency. No consequences if they are not met. The PA wanted to have more control over the tug operators. These requirements costs a lot of financiel inefficiencies for us. We have to have crew on standby 24/7 even if we don't have a job for that day. Also they set a minimum of 5 tugs but we could do it with 4 tugs.

6. What are your objectives when you perform a port call process?
On time with correct asset and Zero lost time injury

7. What innovation would you like to see to improve the port call process?
From a tugs perspective: anything that can create less changes in time and requirements. Flexibility creates efficiency. From a port's perspective: I think its pretty much optimized. Finding balance between flexibility and hard rules. The port has already invested in tools necessary. The port authority takes responsibility of the VTS and Pilot roles which is the two most significant stakeholders in a port call.

Would the port call become more efficient if the PA would also take responsibility over some tug operations?
Well if there would be one tug operator then certain costs can be divided over more jobs. So in that aspect it could if it becomes one operator. In Australia public owned service providers don't tend to go that well. Because of industrial relations with the union en so on. Private companies will find more performance in terms of efficiency.
8. What criteria would be important to you when assessing certain port call innovations?
- Viability – feasible
- Impact for entire chain
- Purpose
- Total profit
- On time

B.6 Port Tanger-Med

Stakeholder: PA Port Call optimization
Date: 9 September 2022
1. The PA is state owned? What is the role of the PA during the Port call process? Who does the planning of the port?

In tanger med our mast office is in charge of planning the port call based on planning of terminals. We take in charge of vessels 2 hours infront with VTS. Pilots are working under TANGER med, they are our pilots it's not another company. Tugs are private but there is a managing activity by the port authority. Whenever we receive a request, the request is automatically sent to the tugs. And then we give notices on the status of the vessel. For example a 30 minutes notice and within 15 they are around the ships. The tugs plan their own assets.

2. Boluda and Svitser are under concession. Are there certain service requirements you require?

We track the tugs activity and measure if there are any delays of movements related to tugs. The VTS can indicate the reason of delay when it occurs. This is the success of tanger med because we are tracking delays for 10 years. It is helpful to analyse. For example, last year we analysed that many delays where because of pilot availability. Pilots said we are sorry but we have a very busy schedule. This analysis was shared with the management of tanger-med and the decision was to employ more pilots.
We have many types of delays possible. For example for a tug we have two: all tugs are occupied or unavailability due to maintenance or something else. A tug cannot be used. We track this for a year and it gives us a idea if we need more tugs or not.
The agreements are all under contracts with the private companies.
4. How does the port of Tanger-Med facilitate port call optimization?

It comes down to tracking the delays and the reasons behind the delays. The VTS analyses the delays. The PA does this analysis twice a year and shares it with the parties involved to talk about the room for improvements. If we are talking about port call optimization it is all about this. We are talking to agents, terminals, tugs, pilots, moores separately. We talk about the KPIs and we have workshops to discuss what happened and about some special cases. At the end we make actions to do. Sometimes these are actions for us and sometimes for them.

B.7 Shipping Company

Stakeholder function: Port Optimisation Manager
Date: 30 August 2022
Meeting: Phone call

1. Ik zie dat u binnen maersk de functie Port Optimisation manager hebt. Wat houdt dat in en waar ben je dan voornamelijk mee bezig?
Bezig bij iptco. JIT imo guide. Greenvoyage. Je wilt port call optimizatie global regelen voor de beste effecten. Haven, nautische diensten en rederijen kunnen dat niet alleen die moeten bij elkaar komen. Traditioneel is iedereen heel behoudend. Transparantie van data is cruciaal. Om het betrouwbaar te houden ontkom je niet aan standaardisering. IHO nautische IMO voor operationele data. Geen globaal platform. Maar kijken naar een oplossing die scaleable is, gestandiseerd data elementen. Verschillende platformen gekoppeld kunnen worden.

Als je data hebt en commerciele data is moet je die beschermen. Data enriched. Zorg element is data governance. Sleepers hebben zorg dat data transparant wordt. Pitfalls dat data voor sancties gebruikt gaat worden.
Commerciele implicatie Expectation management. Er onstaat nog steeds verschillen Gesloten community. Wet en regelgeving gaan belangrijk worden.

3. Wat zijn jullie belangen als rederij tijdens een port call optimalisatie? - Emissies
- Efficiente flow door die havens
- Minimaal delays.
- Connected ports.

4. Zijn er voorbeelden van havens die het heel goed doen en voorbeelden van havens die het heel slecht doen?
Port tangermed in maracco is goed. Omdat alleen containers zijn. Ook is de organisatie daar erg strak. Alles wordt bepaald door de haven authoriteit daar. Geen vrije markt zoals in Rotterdam. Havens in afrika en havens waar je multi-user hebt.
Aard van de haven is ook een bottleneck. Transhipment havens. Import/export liggen meer bottlenecks. Import export blijft op de terminal. Doorvoerhaven. Aanvoer van goederen is lastiger in rotterdam.

C

Port Descriptions

C.1 Port Ras Al Khaimah

C.1.1. Port Overview

RAK Ports is the Port Authority of the Emirate of Ras Al Khaimah area in United Arab Emirates. Three ports are located along the coast of the area: Saqr Port, Ras Al Khaimah Port, and Al Jazeera Port. The main activity of the port is the export limestone and other construction materials with about 1700 port calls per year. The main share of traded volumes is in dry-bulk, container and other cargo volumes are very small. The Port authority can be described as a public full service port by the World Bank Port (Foulquier and Maugeri, 2012). This means that all assets, port labour and operations are owned and managed by the port authority.

C.1.2. The port call

At RAK Ports the operational department is responsible for planning the berth utilization with their customers. A customer has a request to export a certain amount of bulk through a chartered vessel. The operational department will plan this request and coordinate with the Marine department to manage the port call. The Marine department is responsible for arrival and departure process of the vessel. This means they plan and execute the pilotage, tug, and mooring of the vessel. Usually the day of arrival is known several days to 3 weeks in advance. Then 3 days before the arrival the department knows if it will be after midnight of before midnight. As the vessel reaches closer, the ETA becomes more accurate. Once the vessel arrives, arrives it usually goes to anchorage area and when the berth is available Marine call the vessel to the pilot berth area. Once the pilot has boarded and reaches the port, the vessel is assisted with tugs and the linesmen secure the vessel. The Marine department will usually serve the vessel 'first-come first serve' unless the berth is unavailable or the cargo onboard has high priority. When the vessel is secured at berth then the operational department handles the cargo. After handling of cargo, the Marine department is responsible for the departure process of the vessel.

In terms of information sharing and communication, all the necessary information is shared between Marine and Operations department. The Operation department decide on the order the vessels enter the port. This is scheduled around the berth availability. Marine Department has contact with the captain of the vessel about their ETA and the time to arrive at pilot boarding area. The information shared between the vessel agencies and port is always quite accurate. Recently the port has invested in digitising the Port Operating System and the Port Community system with information accessible to all relevant departments and external stakeholders.
The port call of RAK Port is fairly straight forward. It can be compared to the description of Lind et al., 2016. The main difference is that the tugs, linesmen, pilots, and terminal are all part of the port authority and not different (private) stakeholders. This means the requesting and coordinating services between different stakeholders does not happen. All the nautical services are operated through the Marine department of the port Authority. This makes the planning of the port call process less complex compared to other structured ports.

The channel to enter the port has been dredged to certain depth allowing only one large vessels to access the port at a time. Whenever there are few vessels arriving at once there is some waiting time outside the port. The main bottleneck of this port call process is that the marine only allows one pilot

to be operational at once. There is no need for more than one pilot at a time seen that the channel is too narrow to allow two vessels at a time. On top of that only one pilot is used to press costs of the marine department. occasionally it does happen that two vessels enter at once if the second vessel is small vessel, barge or Pilot Exemption Certificate holder. There is enough tug and mooring capacity to handle more than one vessel at once. There are also enough pilots to handle more than currently handled.

As the interviewee from the marine department mentioned (Appendix B), there is no real need to optimise the port call as the berth availability is utilised efficiently and the port call process itself does not have any delays. Only one vessel is handled a time which makes it easy to plan. There is always room for improvements but these are minor. Currently the port is operating under it's capacity.

C.1.3. Port factors

The organisational structure of RAK Ports makes the planning and coordinating of the port call relatively easy. As mentioned earlier, this port can be described as a service port according to the world bank port management structures. The terminals and nautical service providers are all operated, controlled, and organised by the port authority. Because everything runs through 1 entity (between two departments) it makes it easier to coordinate between operations and marine department, according to the harbour master in RAK Ports (Appendix B). This kind of management can be described as centralised management. Logically there is only one entity active in the port.

Another factor that contributes to the efficiency of the port is the fact that only one vessel is serviced at once. This makes the planning work efficiently. The underlying reason is mainly due to geographical restrictions and cost efficient factors. Another factor is the type of industry the port is handling. RAK Ports is mainly dry-bulk export port, the other types of cargo are proportionally lower. There is no multiple berth visits in one port call. The amount of port calls can also be considered as a port factor describing the port environment. In RAK Ports the amount of port calls is not very large and there is enough capacity to facilitate the current amount of traffic.
Having information accessible to the relevant departments and external stakeholders is important. RAK Ports have invested in digitising operation systems like port operating system and a port community system.

C.2 Port of Hamburg

The following section describes the Port of Hamburg. How the port call is planned and organized is also described. The information is retrieved from the website of port of hamburg and conducted interviews found in Appendix B

C.2.1. Port Overview

Hamburg is the third biggest port in terms of TEU in Europe with 8.7 million TEU (Port of Hamburg, 2021). Besides container cargo they also handle dry bulk, liquid bulk and they have cruise terminals for passenger transport. The total number of port calls were 7371 in 2021. The Elbe river is the very narrow gateway to the port making the arrival and departure of vessel complicated. The passages have to be planned and coordinated well. In order to coordinate this well, the hamburg port authority, HVCC and DAKOSY work closely together.

The Hamburg port authority is responsible for the infrastructure of the port area. The port authority of Hamburg can be seen as a landlord model. Meaning they invest and maintain the infrastructure and lease land to the operators. Besides property management, the PA is also responsible for smooth and safe vessel movements on the waterways of the port. This is the Vessel Traffic Service (VTS) center of the Hamburg port authority.

The HVCC is the Hamburg Vessel Coordination Center, a central and neutral organisation where terminals and shipping companies can coordinate the arrival, inter port, and departing movements (“HCVV”, 2022). The HVCC has two departments, Feeder Logistics Center (FLC) and Nautical Ter-

minal coordination (NTC). The FLC is responsible for the planning of feeder vessels and barges. This department is not studied as it lays out of the scope of this research. The NTC is responsible for operational coordination of ultra-large vessels during a port call. Through pooling communication channels, knock-on effects can be recognised in time to find an operational optimal solution in traffic situations, see figure C.1. This makes sure the bottlenecks can be reduced.

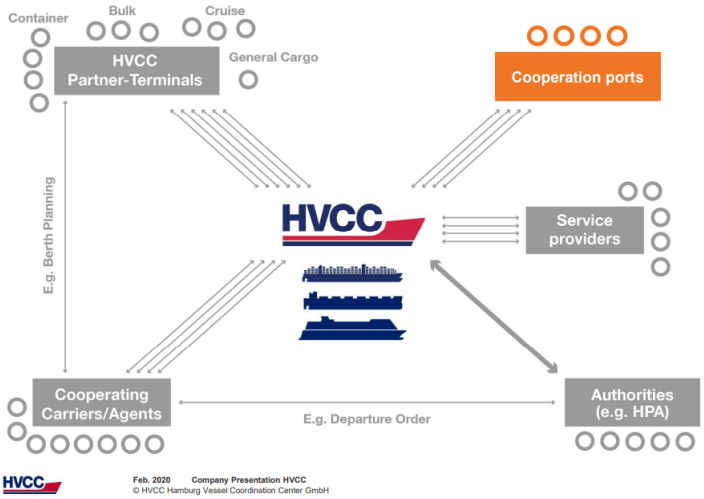


Figure C.1: Communication channels derived from:www.hvcc-hamburg.de

DAKOSY operates and develops the Port Community system for the port of hamburg. The Port Community system has four parts: the port call, import, hinterland, and export. The port call part is most relevant for this thesis. The port community system continuously reports ship positions and calculates time frames data which is used for optimized ship management and coordination on the Elbe river and in the port. DAKOSY works in close collaboration with HVCC.

C.2.2. Port call

As described above, the HVCC is the coordination center for coordinating the arrival and departure processes optimally. The Port authority is responsible for what happens in the port in the next 24 hours. This is called the VTS or VTS, Vessel Traffic Center. Safety manoeuvring in the port. In the end they decided on the vessel sequence. They are neutral in the sense that they do not prioritise one agency above the other because then they would incorporate commercial competition between terminals. By law they are not allowed to do this. They only look at safety. HVCC look forward in time (starting to collect data weeks before vessel arrival) and collaborate with the terminals, vessel shipping lines, the port authority and other stakeholder such as the pilots and tug operator to make a sequence for vessel which have relevant interactions, when manoeuvring in the port. HVCC monitors several weeks in front, what are the plans for the vessel in their voyage via Hamburg. The sequence is made according to restrictions and some soft preferences of the terminals and shipping lines and suggestions of other stakeholder. This sequence is sent to the port authority for approval. They check if it's feasible in terms of only safety. Once It's all checked in terms of safety the sequence is settled. HVCC shares the full planning for the next 3 days so that everyone, who has access to the HVCC dashboards is aware of the current planning situation. Thus, HVCC provides collaboration between all major participating stakeholders linked.

The port call starts with a vessel agency making contact with the terminal to set a suitable berth allocation. The Terminal sends the berth planning to the VTS and to HVCC usually at the same time. The HVCC has a board overview of the planning further in advance than any other stakeholder. About 5 days in advance the HVCC gives the VTS an advice on how to plan the traffic. The VTS can either confirm or require changes if safety cannot be guaranteed.

The upfront planning is very much coordinated between the terminal, HVCC and the VTS. The requests only have come from the terminal making it easier to coordinate the requests. It is more difficult if berth requests come from different sources. About 24 hours upfront, the Planning is finalised by the

VTS and the pilots, tugs and Linesmen can plan their services. Because the HVCC provides good insights further in advance the pilots, tugs and linesmen already have a good understanding of what is going to happen. Planning the resources of the nautical service providers is done individually. In case of real capacity problems the nautical service provider communicates it with the HVCC. This usually doesn't happen in the port of Hamburg.

C.2.3. Port factors

The management structure of Hamburg is decentralized. The tugs, terminals, linesmen and pilots organize there own operations. The PA is responsible for only the safety on the waters of the port. The role of the PA can typically be described as a landlord model by the world bank tool. The nautical restrictions, and number of port calls are the biggest bottlenecks for Hamburg. Hamburg has several nautical restrictions, like narrow and long gateway and tidal windows. The amount of port calls in hamburg has increased to a point where agreements in coordinating the narrow gateway became necessary. The two biggest terminals have set up an independent coordination center, HVCC, to coordinate the traffic more smartly and more in advance. It is important that the HVCC has a strong connection to at least the Port Authority. It is also important that you have good connection with the terminals. This gives access to the berth planning and get lots of insights. These are important aspects for having a HVCC, (Appendix B). A HVCC is necessary in a complex port with lots of interdependencies. Port of Hamburg is complex, in terms of number of stakeholders and amount of port calls, that there was a higher need to coordinate the Port Call. The more vessels and the more stakeholders there are the more interactions there are and thus the more complex a port call becomes. The other stakeholders will follow the HVCC once they see the benefit of getting information further in advance. Also the more inter dependency, the more important a port call coordination can become. The bigger the network the more important it becomes (appendix B).

C.3 Port Antwerp-Bruges

C.3.1. Port Overview

The port of Antwerp-Bruges is the second largest port in Europe with 260 million tons of maritime trade ("Port of Antwerp-Bruges", n.d.). Trade consists mostly out of container cargo and bulk cargo. The port of Antwerp-Bruges is a complex port due to the geographical location of the port. The port is located about 80 km inland on the river Scheldt. The port waterways are both in combined Dutch waters and Flemish waters. This requires an agreement concerning how parties work together to manage the traffic over the Scheldt river. In order to coordinate this well the Antwerp Coordination Center (ACC) plans the port call in an efficient manner. The ACC is responsible for coordinating the nautical services and efficiently making a traffic planning according to available resources.

Besides the port deep inland location the port also has several terminals along the river and several terminals behind locks. For the terminals along the river some deep sea vessels are constrained to tidal time windows meaning they have to berth and depart the port within a tidal cycle. For the terminals behind locks the vessels are constrained by the barrier of the locks. The Vessel Traffic Service is responsible for monitoring safety behind the locks. The VTS can give advice concerning routing, weather conditions, and potential risks.

C.3.2. Port Call

The port has a sailing approach of approximately 8 hours from the anchorage areas to the port. There are two anchorage areas: Steenbank and Oostende. Vessels anchored at Steenbank are served by dutch pilots and the vessels anchored at Oostende are served by Belgium Pilots. That makes the traffic planning more complex. On top of that, there are three types of pilots: A sea pilot, a pilot for the Schelde, and a pilot for in the port. This means a vessel requires three different pilots to get in or out of the port of Antwerp.

Then another complexity are the locks in Port Antwerp. Some terminals are located behind the locks and vessels are thus constrained to the time windows of the locks. On top of that, the nautical services before the locks are privatised entities and the nautical services after the locks are public entities as

part of the port authority. This means there is a transfer of pilots and tugs.

Planning the port call in port of Antwerp is rather complex due to these agreements and organisation. It is the responsibility of the Port Authority to make the vessel traffic planning. The ACC and VTS department work together to make the traffic planning. The ACC is coordinating with all the stakeholders and keeping the constraints of the port in mind to make a port planning. The VTS is responsible for monitoring the safety on a more real-time base.

C.3.3. Port factors

The Port of Antwerp-Bruges is fairly complex and unique. The management of the port is similar to all ports in Europe which is decentralised. This means the tug, pilots, terminals are responsible for organising their own operations. The PA officially takes a Landlord role in the port however the PA is very involved in the port call processes. This is due to the complex national shared waterways where it is necessary to make good agreements between stakeholders. The PA is not only responsible for the VTS but also determines the sequence of vessels entering the port. In a more traditional landlord port the PA is only responsible for the safety of the vessel traffic. The sequence is determined between the terminals and vessel agencies. In Antwerp, good agreements are necessary due to the high traffic and nautical restrictions that Antwerp has. Nautical restrictions like long gateway, locks, and tidal windows make it difficult to organise the port calls. Another factor that makes this port complex is the type of industries active in the port. Container terminals have a consistent frequency of arrival and deviate minimally. However tankers are much more difficult because there arrival frequency is less accurate, their terminals are behind locks, the terminal processes get delayed often, and the liquid tankers need to visit several terminals during one port call.

C.4 Port Arthur

C.4.1. Port Overview

Port Arthur is located in Texas and together with port Beaumont they share the Sabine waterways. In this area there is no port authority. This means the Sabine pilots are operating the incoming vessels for both ports. The Sabine waterways is a very long and narrow approach making it difficult to reach the terminals. The main activity in the port is the export and import of liquid and dry bulk. There are about 50 private terminals. The Sabine pilots act as port authority in the sense that they are responsible for traffic management to the port. The Sabine pilots have served about 6400 vessels in the last 365 days. Furthermore, there are two privatised tug operators, Seabulk being the biggest operator. The Linesmen of Port Arthur are also a private company in the port.

C.4.2. Port Call

Generally a port call request happens between the vessel agent and the terminal. The vessel agent is also responsible for informing the pilots, tugs, and linesmen about their port call. When a vessel is 72 to 48 hours away of arrival, the vessel agency contacts the pilot dispatcher. The dispatch office of the Sabine pilots get a list from the terminals about what day a vessel is going to arrive. It is then the responsibility of the pilots to make a schedule based on the waterway traffic safety. In port Arthur there is no harbour master and the pilots act as the harbour master. The pilots will upload the inbound and outbound vessels to their vessel traffic online website. This website will give an overview of the ETA's and status updates about all vessel. The terminals, tugs, and linesmen all have access to this website. So the pilots decide where and when they need availability. The dispatching office of the tugs and linesmen are responsible for responding to the request as best as possible. They don't really have a choice but to respond to the requests.

The port has a 50 mile long approach with terminals very spread out along the river. This means there are requests from many different places. The demand profile in this geographical diverse port system makes the port call inefficient. There are lots of manoeuvres for both the tugs and pilots. Secondly, there are traffic restrictions which the pilots put in place for safety. For the larger vessels there is day light restrictions. So these vessels have a smaller time window to operate in and this gives them priority. The large vessels are typically convoyed occupying all the tugs for about 6 to 8 hours meaning the activity for other terminals is put on halt. So there is a lot of waiting for the smaller vessels and there

are a lot of inefficiencies that could be improved if planning schedules are put together. The pilots can determine the sequence of vessels. Typically the vessels allocated to the furthest terminal will be inbound first as vessels cannot pass each other in the narrow channel.

C.4.3. Port factors

There are several factors that make the port of port Arthur specific. First of all, the geographical layout of the port effects the efficiency of the port call process in port of port Arthur. The terminals are very spread out leading to long sailing times for tugs and pilots due to the spread out demand. The terminals are spread along the Sabine channel from Port Arthur until Beaumont. Another factor influencing the port call operations is the large vessels are day-light restricted. These vessels are thus only allowed to be manoeuvred during certain time windows and often get priority over the smaller vessels. This causes more waiting for other vessels due to unavailability of tugs. The second factor, port calls, is increasing in the port and it becomes more and more difficult to plan the very largest vessels with day light restrictions. According to the interviews, with the pilots, plans of widening the river is preferred but complex due to land ownership. Thirdly, there are a lot of different stakeholders due to the many terminals. The terminals are different in size and don't all have the incentive to improve the port call. They also don't communicate with each other to coordinate berth planning for example. The responsible stakeholder for the waterway management is a private entity in stead of a public. Pilots have highest authority over waterway traffic. They act as the VTS. The pilots do plan the waterways as efficiently as possible according to the use of the waterways. They don't prioritise commercial interests of one above the other. All the stakeholders in this port are private entities making it a highly competitive market with the willingness to improve own operations as much as possible. An example is where the pilots say the tug operators need more tugs but the tug operators say they need to allocate their tugs more efficiently. The management of this port can be explained as typically decentralised because all the stakeholders are optimising operations for themselves. However the willingness to innovate and improve is higher than a more public port for example. This confirms the conclusion of Van der Lugt et al., 2015, where more business like PA are more prone to innovations in ports.

C.5 Port of Sydney

C.5.1. Port Overview

The PA of new south wales is a group of 4 bigger ports, Sydney harbour, Port Botnay, Port Kembla, and Newcastle Harbour. Combined they are good for about 5800 vessel movements a year. The cargo industries are mostly dry and liquid bulks, containers, and passengers. The ports with the most activity is Newcastle harbour and Port Botany. These ports all fall under the same port authority and are organised in a similar way. The Port Authority provides the VTS service and the marine pilotage service. The VTS service is responsible for the port planning. The other services are executed by private entities. The tug operations is however a licensed activity. There are two entities that hold a license. This means that the PA manages certain capacity and service levels in the port. This enables the port authority to manage the performance. According to the World Bank management model it can be referred to a landlord model, however the PA has some extra control by providing the pilotage service and licensing the tug operations.

The ports are spread out along the coast of the new south wales province of Australia. Thus services are not shared between the ports, each port can be considered as one port system. The ports are located along the coast with a relatively short sailing distances.

C.5.2. Port Call

The PA takes a coordination role in organising the port call. Their goal is to safely manoeuvre the vessels according to the restrictions. The PA takes responsibility over the VTS and pilotage. This way the PA has the main control over the port call. The berth request of a vessel happens as it does in most ports, it starts with the vessel agency contacting the terminal to book a berth slot. Once agreed on a slot the vessel agencies contacts the PA and the port call is registered in their PCS. All the nautical service providers have access to the PCS so once the vessel is booked the tugs and linesmen are informed about the job. If the job is not possible due to weather or safety conditions the VTS coordinates the alternatives with the vessel agent. The VTS doesn't take any commercial factors into account. They

are solely focused on coordinating traffic in a safe manner. The tugs provide their capacity problems through the PCS or directly contact the PA. This port call process typically is planned about 60 hours upfront. A minimum requirement is two hours, however availability can then not be guarantied.

From the interview with the PA (see appendix B), it is mentioned that the port call process is running smoothly. With the amount of vessels moving in and out of the Sydney harbour and port Botany, there is no defining factor in terms of capacity. The efficiency on the waterside of the operations is not a problematic factor at the moment. It is mentioned that the port has already innovated as much as necessary to help the jobs of the tugs, linesmen, and vessel agencies.

C.5.3. Port factors

This port is relatively efficient in terms of port call processes. The reason for this is that the geographical layout of the port is simple due to little restrictions and short sailing approach. Also the number of port calls is not significant high compared to the capacity the port has. According to the interview with the PA, the port is operating under it's capacity. The port of Sydney has several industries combined, mostly container cargo and rest is dry and liquid bulk. For this port it doesn't seem to impact the port call process as the minimum registration time for a vessel is two hours upfront. This is much shorter than other ports. This is because of the simple nautical gateway and the capacity surplus. In port Sydney the pilots are managed under the PA and other services are licensed. Generally speaking it can be seen that pilots have a central en coordinating role during the port call process Nikghadam et al., 2021. When a PA takes this task in house, it leads to high control over the port call processes. This means PA takes a more dominant role in the port. One could even argue that the role of the PA is more service like than a true landlord. However, the port is still considered to be managed decentralised and the role of the PA is officially a landlord model. It is however a different model compared to the European ports. Furthermore, the number of stakeholders is relatively lower than other comparable ports. The port of Sydney can be seen as a quite efficient port in terms of port call processes.

C.6 Port Tanger-Med

C.6.1. Port Overview

Port Tanger-Med is located in the north of Morocco opposite of the coast of Gibraltar. The port mainly cargo is container cargo with about 9 million TEU a year. Furthermore, there are some passengers and Ro-Ro cargo. The port has two major terminals, an APMT terminal and a Eurogate terminal. The Port Authority is a state owned authority. Their mission is to focus on management and development of infrastructure, the coordination and operation of the Port community and guarantees the reliability and performance of the services provided to the Port's customers ("Mission and Organization - Tanger Med Port Authority", 2022). The Port Authority provides the VTS service and the marine pilotage service. The VTS service is responsible for the port planning. The other services are executed by private entities. The tug operations is however a licensed activity. There are two entities that hold a license for 25 years. One entity for each terminal. The linesmen are also licensed in the port. According to the World Bank management model the port can be referred as a landlord model, however the PA has some extra control by providing the pilotage service and licensing all services for a longer time. Port Tanger-Med can be considered as a very well performing port as it is the third best port on the Container Port Performance Index (CPPI).

C.6.2. Port Call

In port Tanger-Med the PA takes a more dominant role during the port call process. They are the central point of contact for all involved stakeholders of a port call. The PA takes responsibility over the VTS and pilotage. This way the PA has the coordinated control over the port call process. The port call process is similar to a typical process described in the literature research. The master office is in charge of the planning of the port call based on the planning of the terminals. The VTS has radio contact with the vessel about 2 hours upfront and the necessary berth information is automatically communicated to the nautical service providers so they can act accordingly. Furthermore the PA gives notices on the status of the vessel.

The PA tracks all the nautical activities during the port call and measures any delays with the reason

of delay. Then the PA analyses the delays and talks about performance with the nautical services twice a year. The room for improvement can go both ways. They talk about the KPIs and have workshops to discuss what happend in special cases to improve in the future. This has improved the waiting time of vessels over the past 10 years massively.

C.6.3. Port factors

As Port Tanger-Med scores very well on the CPPI, the port can be considered as a good performing port. As mentioned earlier, the PA has a landlord management structure with licensed activities, meaning the tugs and linesmen are licensed activities. The pilot organisation is part of the PA. This is the main determining factor for this port. Other factors that could be important is the industry type and nature of the port. Meaning Tanger-Med mostly has only container cargo and the port is very much a transshipment port meaning there is not much cargo flow coming from hinterland. The containers enter the port, stay in the terminal, and get picked up by other vessels. Furthermore, the nautical restrictions in the port are limited. Their port is not very geographically complex.

D

Criteria Selection

D.1 Mentioned Criteria

	A	B	C	D	E	F	G	H	I
1	**Harbour master RAK ports**	**Seabulk Tug Port Arthur**	**Sabine pilots**	**PA Antwerp**	**HVCC Hamburg**	**NL Loodswezen**	**Port Sydney**		**PSA Terminal Antwerpen**
2	Costs made by marine services	Main:	It would have to work	Efficiency	Safety	Tijd aan boord	Safety		On time arrival
3	Efficiency to maximize revenue	Safety	Reliable	Delays	minimize delays of vessels	Capaciteit	efficient operations		Aansluiting op shift dienst
4	Amount of ships handled per ye	Operational efficiency	Smart	Deviation	Time deviation of orginal plans	Vertraging van een schip	% of time a pilot serves a		Inzet van ploegen
5	On time operations	Resource Availability	Less waiting time on vessels	Safety	Reliability of suggested plans	Wachttijden	On time arrival tugs		Turn-around time berth
6	Optimal asset allocation	Utilization	Safety		Amount of unsolved conflicts	Tijdig data beschikbaarheid	Servicing as scheduled		Uitwisseling uitgaande en
7	Quick executed operations	Sub Criteria:	Efficiency – move as many shi		Port call efficiency	Betrouwbare data deling	Max. Dangerous incident		Goede coordinatie
8	Fuel efficiency	Out of service time	Amount of vessels			Efficiency – Betere inzet van r			Keten capaciteit
9	Avoiding damage	Cause out of service	Rest time			Veiligheid	Engage Marine		Veiligheid – afmeer afstan
10	Avoid Marine indicidents	Lost time injuries	Pilot hours				On time		
11	Zero injuries	recordable injuries	Close calls				Viability - feasbility		
12	Zero fatalities	near miss reports					impact on the chain		
13	Avoidance of pollution incident	Delays					purpose		
14		Manning issues					total profit		
15		Tug utilization					CAPEX		
16	**RAK Ports**	Volume of jobs							
17	Costs effective	Engine hours							
18	Time Efficient	Revenue per job							
19	Safety	Fuel consumption							
20	User friendliness								
21	Add value to port	**Seabulk**					Costs	6	
22		Fuel savings					Efficiency (operations)	13	
23	**CEO RAK Ports**	Crew down time					On time	17	
24	Bezettingsgraad van je assets						Assets efficiency	9	
25	Optimaal benutten van je assets						Effectivness	4	
26	Flexibiliteit van je assets						User-friendliness	3	
27	Gelijkmatige toegang tot inform						Flexibility	2	
28	informatie deling						Reliable	3	
29	User-friendliness						Safety	12	
30	Easy to use (laag drempllig)						Data availability	3	
31	Reduce incidents								
32	Sluit goed aan op praktijk								
33	Effectiveness								
34	Reduce deviations to planning								
35									

Figure D.1: Criteria Ordening from Stakeholders

D.2 Explanation of categories

The performance attributes should be specific and fall under the overarching category. For the Bayesian BWM it is not possible to evaluate more than 9 attributes. So a set within a category cannot be bigger than 9 attributes. Otherwise further clustering is necessary. The performance attributes have been divided into the main categories: *Commercial effects, Operational effects*, and *Safety effects*. These categories cluster the found attributes from literature and interviews on a equal hierarchical level. Thus for these reasons it has been added to operational effects. The overview is presented in table 5.5. This has lead to the proposed list of attributes.

D.2.1. Commercial

The commercial effect of innovations is an important performance attribute in the transport field. Within the field of literature, commercial effects are also often mentioned attributes. Attributes like, total costs, profitability and value added are related to financial attributes. Usually the companies active in a port are mostly privately owned companies with commercial interests. Thus the commercial affects of a innovation will be an important aspect to the whole port call chain. This became further noticeable during the semi-structured interviews, many stakeholders mentioned that innovations should bring more benefits than it costs. For stakeholders to adapt an innovation it must be commercially interesting for them. If it costs more than it will deliver, the innovation doesn't make sense. For these reason it is important to include commercial effect as main attribute during the decision making of port call innovations. Attributes that explain the commercial impact are the total OPEX and CAPEX of the innovation to the port call process. The added value it brings to the port call process and effect on the number of port calls. These are attributes that could be important for all port call stakeholders but not all equally important.

D.2.2. Operational

Operational related attributes are the most mentioned attributes during the interviews. This cluster includes the most sub-attributes out of all main categories with 9 sub-attributes. The reason for that many attributes could be explained because, it is easy for interviewees to relate to their own operations during an interview. Additionally, the operational impact usually has an effect on commercial factors. The operational attributes generally describes how an innovation impacts time efficiency and the use of resources during a port call process. There are 3 sub-attributes related to time efficiency. Delays during the port call must be mitigated. This has been mentioned in literature by many studies. On time is a factor that is mentioned most often by stakeholders. If all activities runs on time then there are no waiting on each others services. The attribute on time is expected to score as important for the stakeholders as it is often mentioned. Environmental affect is the impact a innovation has on the environment in terms of emissions. One could argue that an environmental impact should get an own cluster however, during interviews it became clear that not many companies see this as a main driver to improve the port call process. Improving the port call process will automatically lead to improved environmental affects due to reduced fuel consumption for example. The environmental affects are interwoven in operational impact. Furthermore, sub-attributes related to the use of assets are both mentioned in studied literature and during interviews. Assets must be utilised in an efficient way by all stakeholders. The sub-attributes: flexibility, availability, reliability, user friendliness are attributes more related to operational requirements. Whether the innovation is data driven or not, it is important that the innovation works and fits the operational requirements. Alternative requirements have been mentioned by some interviewees, but not many. It will be expected that these requirement attributes score slightly lower than some performance attributes.

D.2.3. Safety

Safety attributes contains the least sub-attributes, when implementing a new innovation it is very important that is does not lead to more incidents and damages. Safety is a attributes mentioned by almost all stakeholders during interviews. Besides running the port call process efficiently, safety is also an important factor. It can be argued that safety is the most important attribute. The purpose of having a pilot and tug onboard is to manoeuvre safely through the port. This is one of the main objectives of a port call process. Thus it will be interesting to see how safety gets scored compared to operational impact. Safety is defined by incidents and near misses. Introducing a new innovation

should not negatively influence the safety in the port. The sub attribute (cyber-) security has been added as this can become an important factor when sharing more data with each other or implementing innovations like remote pilotage. The last attribute, robustness, is more a requirement the innovation should have. Robustness means the attributes is robust against adverse conditions during the port call. It can also be understood as resilient to errors.

D.3 TOE Framework

	A	B
1	**Main Criteria**	**Sub Criteria**
2	Technology	OPEX
3		CAPEX
4		availability
5		reliability
6		robustness
7		number of port calls
8		asset utilization
9		flexibility
10		effectiveness
11		security
12		
13	Organisation	Delays
14		On time process
15		turn-around time
16		incidents
17		near miss reports
18		user friendliness
19	External task environment	added value to port call
20		
21		

Figure D.2: Criteria categorised according to the TOE Framework

E

BWM Results

E.1 BWM Survey

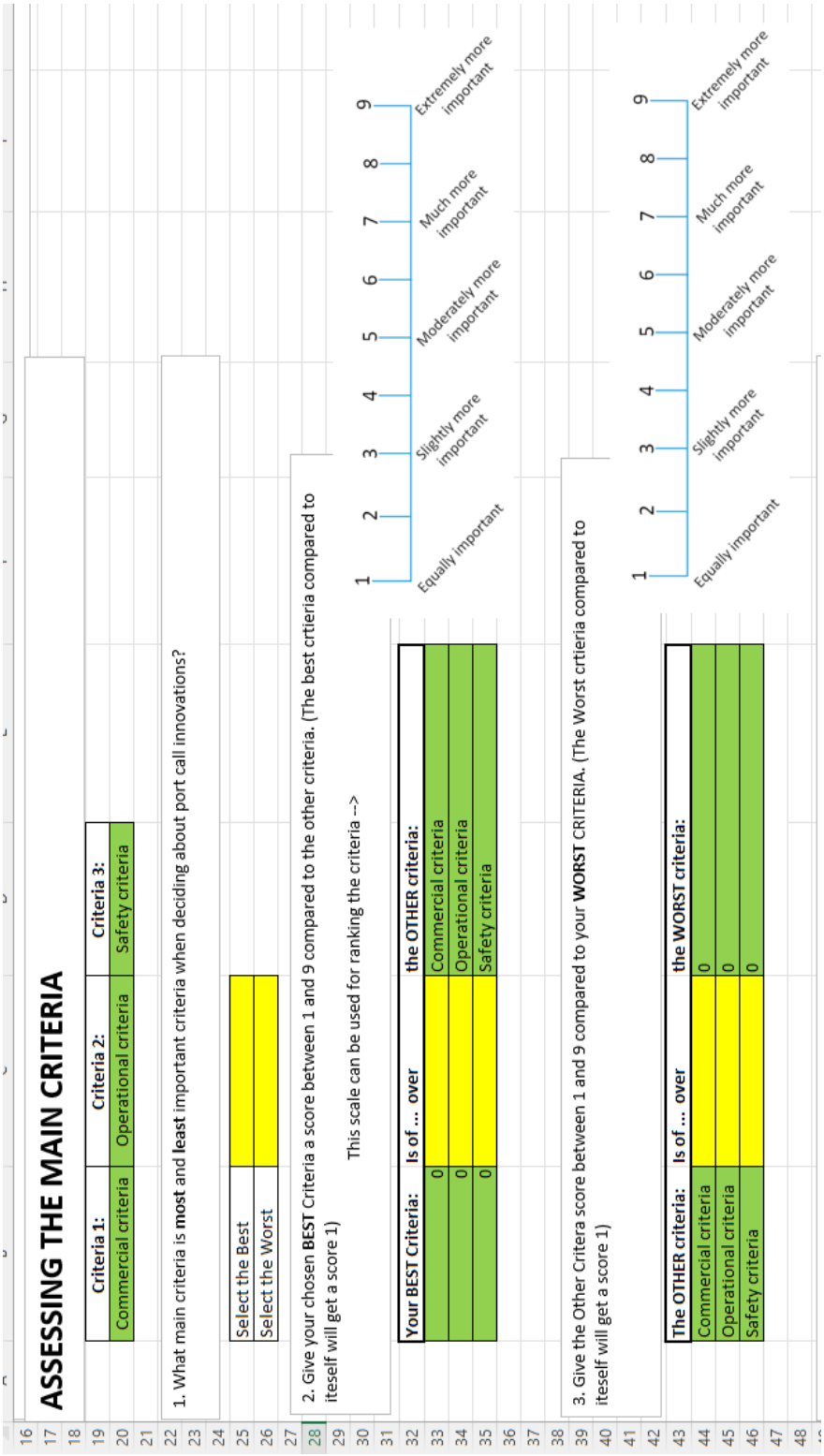


Figure E.1: Screenshot of BWM Survey

E.2 BWM Results marco level

Table E.1: Overall Weights of attributes for evaluating port call innovations

Main category	Local weights	Sub-attributes	Local weights	Global weights
Commercial effects	0.204	OPEX	0.192	0.039
		CAPEX	0.190	0.039
		Added value to port call	0.437	0.089
		Number of port calls	0.181	0.037
Operational effects	0.369	Delays	0.121	0.045
		On time processes	0.147	0.054
		Turn-around time	0.112	0.041
		Environmental affect	0.100	0.037
		Asset Utilisation	0.118	0.044
		Flexibility	0.095	0.035
		(Data) Availability	0.105	0.039
		(Data) Reliability	0.120	0.044
		User-friendliness	0.083	0.030
Safety effects	0.427	Incidents	0.337	0.144
		Near miss reports	0.235	0.100
		(Cyber) Security	0.188	0.080
		Robustness	0.240	0.102

E.3 BWM Results from ports

E.4 Weights from studied Port

The weights of the attributes are presented per port. This thesis has received surveys from 5 out of the 6 studied ports. The results are presented in tables below.

E.4.1. Weights from RAK Ports

The final weights from the RAK Ports are presented in table E.2.

Table E.2: Weights of attributes in RAK Ports

Main attributes	Local weights	Sub-attributes	Local weights	Global weights
Commercial attributes	0.455	OPEX	0.202	0.092
		CAPEX	0.202	0.092
		Added value to port call	0.476	0.216
		Number of port calls	0.120	0.054
Operational attributes	0.302	Delays	0.124	0.038
		On time processes	0.144	0.044
		Turn-around time	0.124	0.037
		Environmental affect	0.107	0.032
		Asset Utilisation	0.107	0.032
		Flexibility	0.089	0.027
		(Data) Availability	0.103	0.031
		(Data) Reliability	0.133	0.040
		User-friendliness	0.069	0.021
Safety attributes	0.244	Incidents	0.312	0.076
		Near miss reports	0.247	0.060
		(Cyber) Security	0.246	0.060
		Robustness	0.195	0.048

The final weights of RAK Ports has been determined by two respondents, namely the harbour master and the port manager from the PA. These are good representations for the interests of a port call process. In RAK Ports centralised, service management model meaning the role of the PA is to be responsible for all operations and services. For this reason, there is no need to gather respondents from tugs, pilots, terminals etc. The individual preferences were not fully similar, the most important attributes was both commercial, however their worst attributes was different. Two respondents from the same organisation can have different preferences due to their role within.

Out of the main attributes, the commercial attributes (0.455) is considered as most important. The argument was that a port call innovations must be commercially interesting otherwise it will lose the PA money. The *Operational attributes* (0.302) can be considered as second most important attributes. The PA is operationally active in the port and does benefit from efficient operations themselves. Contrary to the overall results, *Safety attributes* (0.244) is scored lower. The difference between operational attributes and safety attributes is not very big. When looking at the credal ranking (figure E.2), it can be said with 63% confidence that operational is superior over safety. A possible explanation could be that in RAK Ports only one vessel enters at a time and safety within the port call doesn't need improvement. Thus the main important attributes are Commercial and Operational attributes which is in line with the expectations seen the context factors of the port.

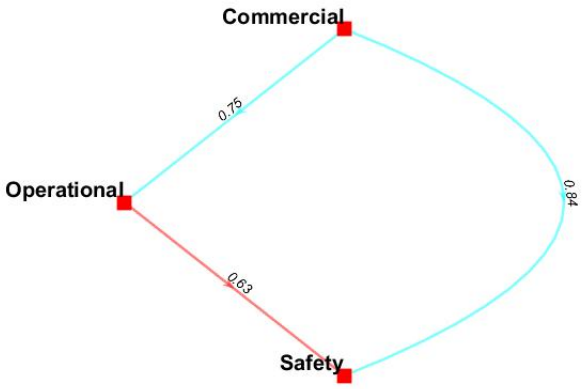


Figure E.2: Credal Ranking main attributes of RAK Ports

When looking at the global weights, the most important attributes is *added value to port call* (0.216). This means the most important attributes for a new port call innovations is that it adds value to the port call and in this case the PA. Seen that the value stays within the PA, it is thus quite logical that *added value* is scored as most important. The second and third most important attributes are *OPEX* and *CAPEX* (0.092). This means the investment costs of the innovation is relatively important to RAK Ports. The fourth most important attributes is *incidents* (0.076). This is in line with the safety objectives of the port call overall. The lowest attributes is *flexibility* (0.003) and *user-friendliness* (0.021). The attributes related to requirements are scored lower than the attributes that indicate an affect of port call innovations.

In general it can be said that RAK Ports values the commercial attributes and operational attributes relatively high. This is due to the active role of the PA in the port. In RAK Ports there is less necessity to improve the port safety due to the lower traffic on the waterways. Controlling the costs and creating value for to the port is important for RAK Ports.

E.4.2. Weights from Port Antwerp-Bruges

The final weights from the port Antwerp-Bruges are presented in table E.3. These weights have been determined by 3 stakeholders: the PA, a tug operator, and terminal operator. Surprising all 3 stakeholders score the main attributes in similar order but with different weights. For all stakeholders Safety is most important and commercial is the least important.

Table E.3: Weights of attributes in Port Antwerp-Bruges

Main attributes	**Local weights**	**Sub-attributes**	**Local weights**	**Global weights**
Commercial attributes	0.133	OPEX	0.139	0.019
		CAPEX	0.183	0.024
		Added value to port call	0.525	0.070
		Number of port calls	0.154	0.021
Operational attributes	0.346	Delays	0.150	0.052
		On time processes	0.134	0.046
		Turn-around time	0.107	0.037
		Environmental affect	0.092	0.032
		Asset Utilisation	0.107	0.037
		Flexibility	0.125	0.043
		(Data) Availability	0.111	0.038
		(Data) Reliability	0.119	0.041
		User-friendliness	0.055	0.019
Safety attributes	0.521	Incidents	0.363	0.189
		Near miss reports	0.237	0.124
		(Cyber) Security	0.197	0.102
		Robustness	0.203	0.106

For the included port call stakeholders in Port Antwerp-Bruges, the most important main attributes is the *safety attributes* (0.521) which means when deciding a port call innovations, it must lead to safe port call operations. *Operational attributes* (0.346) can also be considered as important attributes to the port call stakeholders. *Commercial attributes* is clearly outperformed and least important to the stakeholders. Two reasons could explain this result: Firstly, the PA has a less active role in Antwerp and the VTS only supervises Safety in a port. Secondly, respondents indicated that commercial attributes depend on operations. If something scores well on operational attributes then it will score well on commercial attributes. When looking at the credal ranking, a clear order can be seen figure E.3. The attributes have a high confidence level over each attributes, meaning safety is superior over operational and operational is superior over commercial.

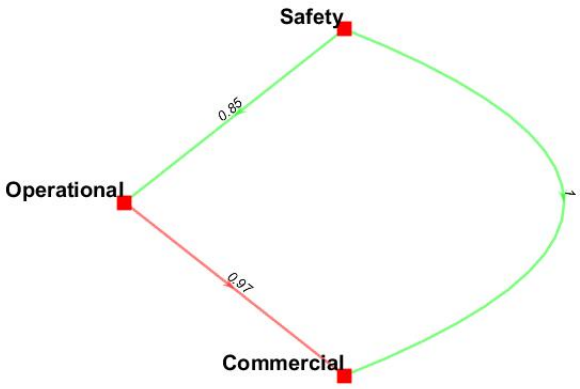


Figure E.3: Credal Ranking main attributes of Antwerp-Bruges

For the port of Antwerp-Bruges, the global weights of the 4 safety attributes are logically scored highest. There after is the attributes *added value* (0.070) scored as important attributes. This means it is relatively important for the stakeholders that the innovation brings added value to the entire chain. This could explained by the fact that the respondents of the BWM have a more system level approach to the port call. In the Port of Antwerp-Bruges the involved stakeholders are in early stages of collaborating by talking to each other about the port call processes. Furthermore, the attributes are relatively close to each other, meaning they can be considered as equally important. The rest of the commercial attributes and *user-friendliness* are an exception and score lowest. It can be said that the port of Antwerp-Bruges is not very commercial driven as these attributes score low compared to other ports.

The confidence of the superioirty of the commercial attributes is presented in figure E.4. As expected, the relation of *added value* with other attributes has full superiority. The weights of CAPEX (0.183), No. of port calls (0.154), and OPEX (0.139) are closer to each other. This is also noticable between in the credal ranking. The confidence ratio between no. of port calls and OPEX is 0.6, which is not much higher than the threshold value of 0.5. It cannot be said that no. of port calls is superior to OPEX. Similar with the relation CAPEX and No. of port calls. The other credal ranking schemes are presented in appendix F.

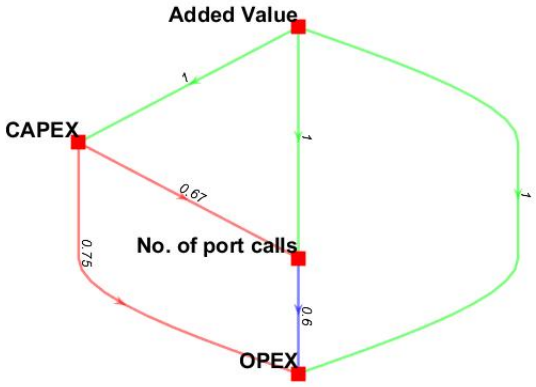


Figure E.4: Credal Ranking within Commercial attributes of Antwerp-Bruges

E.4.3. Weights from Port of Port Arthur

The final weights from the port of Port Arthur are presented in table E.4. The weights are determined by 3 stakeholders: the pilots and two from the tug operators. The two tugs score weigh attributes identical but different to the pilots. There is a slight difference in preference in this port.

Table E.4: Weights of attributes in Port of Port Arthur

Main attributes	Local weights	Sub-attributes	Local weights	Global weights
Commercial attributes	0.153	OPEX	0.217	0.033
		CAPEX	0.197	0.030
		Added value to port call	0.315	0.048
		Number of port calls	0.271	0.041
Operational attributes	0.353	Delays	0.130	0.046
		On time processes	0.130	0.046
		Turn-around time	0.111	0.039
		Environmental affect	0.070	0.025
		Asset Utilisation	0.130	0.046
		Flexibility	0.115	0.040
		(Data) Availability	0.106	0.037
		(Data) Reliability	0.110	0.039
		User-friendliness	0.098	0.034
Safety attributes	0.495	Incidents	0.350	0.173
		Near miss reports	0.140	0.069
		(Cyber) Security	0.199	0.098
		Robustness	0.311	0.154

For the included port call stakeholders in port of Port Arthur, the most important main attributes is the *safety attributes* (0.495) which means when deciding a port call innovations, the score on safety is

most important. Safety is a common factor for the port call. *Operational attributes* (0.353) can also be considered as important attributes to the port call stakeholders. The port call process should run efficiently without any delays. Commercial attributes (0.153) is considered as least important. Operational efficiency will automatically lead to commercial impact. Interestingly, the weights are scored fairly similar with Port Antwerp-Bruges. Some differences can be seen when analysing the global weights.

When looking at the global weights, the 4 safety attributes logically are score highest. Then after, the other attributes score relatively close to each other meaning they can be considered as equally important. This can also be seen in the confidence levels (appendix F). Environmental affect is the only exception as this attributes scores the lowest (0.025) of all. Thus environmental affect can be considered as least important attributes in port of Port Arthur. This is inline with the results of the interviews (appendix B), where interviewees indicated that environmental affect is not yet a first motivator. It is more an affect of efficient operations.

The confidence of the superiority of the main attributes over each other is presented in figure E.6. All the attributes can be considered superior to the other attributes with a confidence of at least 0.78. The credal ranking of the sub-attributes are presented in appendix F. For the sub-attributes of operational attributes, delays in relation to on time show similar weights and have a confidence value of 0.5. This means the two objectives are equally important. Similar with the attributes *asset utilisation*, these three attributes can be considered equally important.

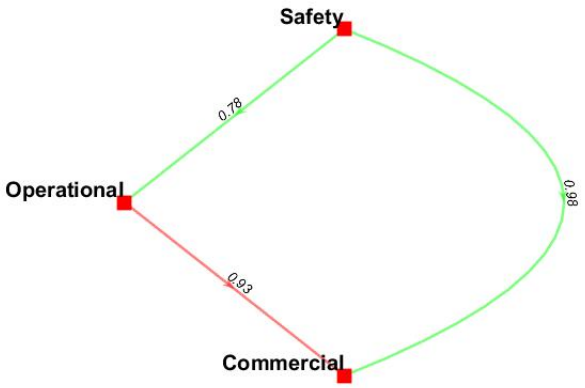


Figure E.5: Credal Ranking main attributes of Port Arthur

E.4.4. Weights from Port Sydney

The final weights from the port of Port Arthur are presented in table E.5.

Table E.5: Weights of attributes in Port Sydney

Main attributes	**Local weights**	**Sub-attributes**	**Local weights**	**Global weights**
Commercial attributes	0.327	OPEX	0.243	0.080
		CAPEX	0.143	0.047
		Added value to port call	0.425	0.139
		Number of port calls	0.189	0.062
Operational attributes	0.302	Delays	0.110	0.033
		On time processes	0.139	0.042
		Turn-around time	0.139	0.042
		Environmental affect	0.121	0.037
		Asset Utilisation	0.117	0.035
		Flexibility	0.080	0.024
		(Data) Availability	0.066	0.020
		(Data) Reliability	0.103	0.031
		User-friendliness	0.125	0.038
Safety attributes	0.370	Incidents	0.315	0.116
		Near miss reports	0.297	0.110
		(Cyber) Security	0.177	0.065
		Robustness	0.211	0.078

The weights of Port Sydney have been determined by two stakeholder. The PA and the tug operator operator, thus the weights don't represent the full perspective of the port call. These weights represent the interests of the PA and tug operator in the port of Sydney. The attributes have been weighted very differently compared to each other. This can be seen by how close the main attributes are weighted and by the low credal rankings in figure X. The most important main attributes for this tug operator in Sydney is *Safety attributes* (0.370). *Commercial attributes* is second best attributes (0.327) and closely followed *operational* (0.302) attributes. These scores are very close to each other because the tug operator values commercial very high and the PA values Safety very high. Two very opposite weighting of attributes. It can be said that the interests difference in Port Sydney between the PA and Tug operator is very high.

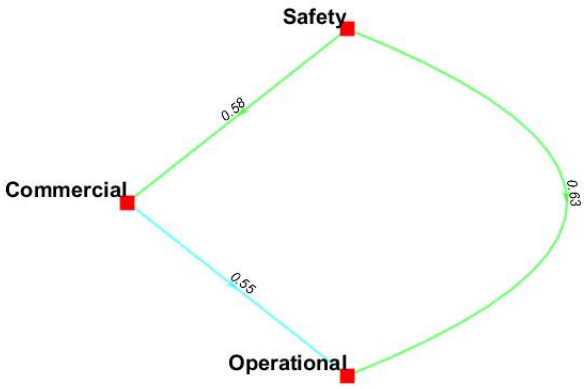


Figure E.6: Credal Ranking main attributes of Port Sydney

When looking at the global weights of the attributes, again *added value* (0.139) is considered the most important attributes. This means it is most important that the port call innovations adds value to the port call process. It should generate more value than the innovation costs. Incidents and Near misses are the next most important attributes (0.116 and 0.110 respectively) meaning the innovation should score well on safety. These attributes is especially important for the Port Authority. The Tug Operator find commercial attributes more important.

E.4.5. Weights from Port Tanger-Med

The final weights from the port Tanger-Med are presented in table E.6.

Table E.6: Weights of attributes in Port Tanger-Med

Main attributes	Local weights	Sub-attributes	Local weights	Global weights
Commercial attributes	0.100	OPEX	0.064	0.006
		CAPEX	0.119	0.012
		Added value to port call	0.521	0.052
		Number of port calls	0.297	0.030
Operational attributes	0.575	Delays	0.151	0.087
		On time processes	0.269	0.154
		Turn-around time	0.034	0.019
		Environmental affect	0.101	0.058
		Asset Utilisation	0.076	0.043
		Flexibility	0.076	0.043
		(Data) Availability	0.151	0.087
		(Data) Reliability	0.101	0.058
		User-friendliness	0.043	0.025
Safety attributes	0.325	Incidents	0.466	0.151
		Near miss reports	0.259	0.084
		(Cyber) Security	0.172	0.056
		Robustness	0.103	0.034

The weights for the port of Tanger-Med has been determind by the PA only. The single respondent is the PA, thus the weights are from a stakeholder who represents the port as a whole. Unfortunately it doesn't represent multiple perspectives from the entire port call. Never the less the PA of Tanger-Med values operational attributes as most important (0.575) where after safety attributes (0.325). The PA of Tanger-Med is very much involved in the port call processes and thus it is in line with expectations that they score relatively higher on operational attributes compared to other ports. It will be interesting to see how the PA of Tanger-Med compares to the PA of other ports. This will be analysed in the next section.

E.4.6. Comparison between ports

Unfortunately not all 5 ports can be compared with each other because the respondents of the survey are not similar in all ports. Thus differences could be dependent on the differences in stakeholders perspectives. When comparing the weights of the main attributes for all the ports some notable findings can be pointed out. Figure E.7, is a bar chart of the the main weights in each port. The weights of Port Antwerp-Bruges and Port of Port Arthur are scored very similar with *Safety* being the most important. This outcome is not particularly expected because the ports have different port context factors. This is a logical outcome for Port Antwerp-Bruges as the respondents are less commercially driven. For port of Port Arthur it is more surprising as this is a port without a PA. The stakeholders are more commercially orientated in this port. When looking at the individual responses, the two respondents from the tug operators have both valued safety as most important attributes by quite a margin leading to these results. A possible explanation for the tugs scoring safety important is that the nautical waterways of Port Arthur is quite complex and narrow. Port Antwerp-Bruges also has a complex structure of nautical restrictions with locks ect. Thus this can explain the similar scoring of these ports. Nautical restriction are a very determining factor in the port call process and this can be seen in the preferences of the stakeholders for these two ports.

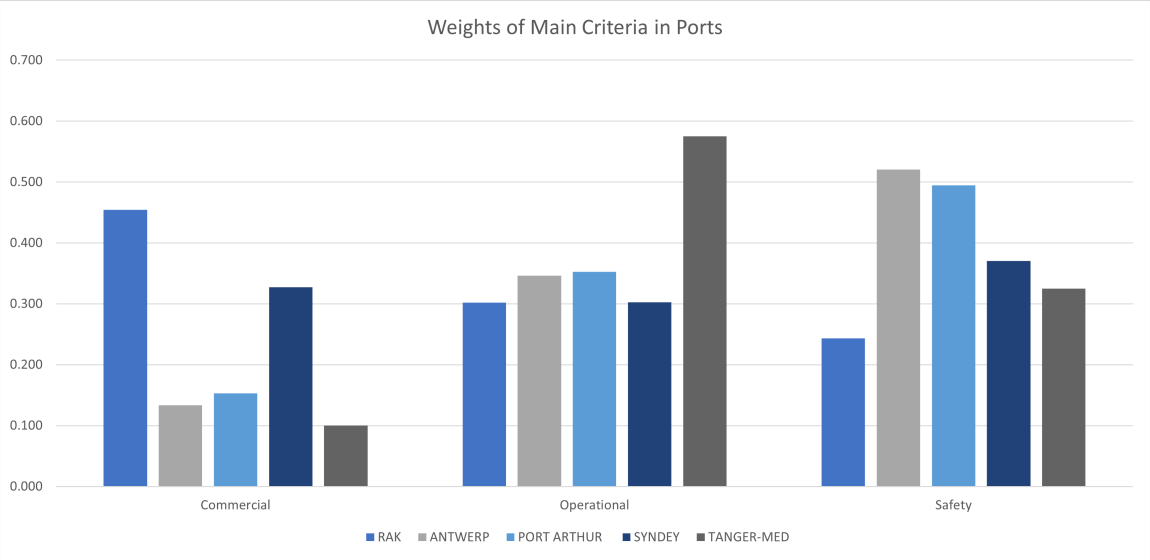


Figure E.7: Weights of Main attributes in all studied ports

Another notable finding is the difference between RAK Ports and Tanger-Med. The respondents are both solely from the PA's perspective, thus these results can be compared. RAK Ports scores commercial attributes as most important where Tanger-Med scores commercial as lowest. Port Tanger-Med scores operational attributes the most important. This could be explained by the context factors of the two ports. RAK Ports has a service management model where all services are operated by the PA. The Port is known for it's cheap and efficient handling costs. Also operationally they are very efficient thus it is logical they score commercial attributes as most important and operational as least. Tanger-Med is a landlord management model with licensed services in the port. The PA monitors and coordinates the performance of the services. Thus they are interested in operational efficiency. Tanger-Med is a very well performing port with higher port calls compared to RAK Ports. The operational efficiency determines the port competitive position, which appears to be most important to the PA of Tanger-Med.

When further analysing the global weights of each port some more specific findings are noticeable. Figure E.8, is the bar chart for the global weights in each port. When comparing RAK Ports and Port Tanger-Med, the same conclusion as before is visible. RAK Ports values *Added value* and *CAPEX* as important attributes. These attributes are focused on costs and benefits. Port Tanger-Med values attributes: *Delays* and *On time processes* as important. These attributes are more related to time and turn-around time in a port. It can be said that RAK Ports, with efficient handling of vessels, have more interest in commercial attributes like costs and value. Port Tanger-Med, with more port calls and high CPPI, has a higher interested in operational attributes like on time processes. The PA in Tanger-Med is focused on port performance on a port system level.

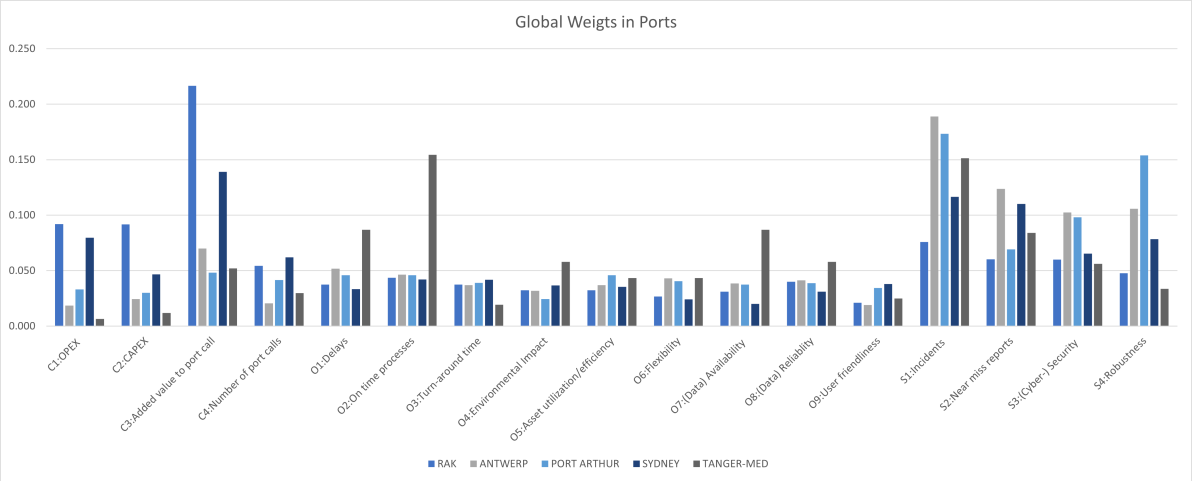


Figure E.8: Global Weights of attributes in all studied ports

As mentioned earlier, the port Antwerp-Bruges and Port Arthur have scored attributes fairly similar. Taking a closer look at the global weights one minor difference can be explained. Port Arthur values *number of port calls* slightly higher than Port Antwerp-Burges does. Port Arthur is a more private port without PA which could explain why amount of port calls is important. This determines the amount of jobs for the nautical service providers. Port Antwerp-Bruges values *added value* slightly higher than Port Arthur. Port Antwerp-Bruges has a more system level approach to the port call due to it's complex nautical restrictions. However the differences are very minor so it could also be up to coincidence.

Due to the varying amount of respondents in each port, not a full picture of the interests can be given. Still some lessons can be taken from the ports. First of all, similar to concluded above, safety is either most important or close to most important for all studied ports. When taking a closer look at how the ports weighted the attributes, it is apparent that port Antwerp-Bruges and port of Port Arthur score similarly. This outcome is was not expected but interesting as the two port share some similarities but also have differences. Port Antwerp-Bruges is nautically very complex with a decentralized management. Port of Port Arthur is also nautically very complex with decentralized management, however this port doesn't have a PA. The pilots are in charge of the traffic on the waterways. On top of that the industries differ. To say that the management role of the PA has no influence on the preferences of the attributes is too short sighted from solely these results. The respondents of both ports cannot be compared because stakeholder's perspectives are not the same. Thus it is difficult to explain the similarity by the port context factors. Contrary, the results from RAK Ports show a high preference for commercial attributes. RAK Ports has a centralised management with service role of the PA, on top of that the port call is already operational efficient but the port's objective to stay cost efficient in bulk handling. This could explain the high preference for commercial attributes. Furthermore, Port Tanger-Med distinguishes itself with high preference for operational attributes compared to other ports. Even though the port is represented by only one respondent, the PA in Tanger-Med plays a dominant role in port performance. The port does have a landlord model, however with own pilots and all services licensed. Tanger-Med is performance oriented which explains the preferences for operational attributes like delays and on-time processes. The more involved the PA is in the port call processes, the more operationally driven. This is noticeable because the other ports score operational attributes lower. Another observation is that Tanger-Med scores the attributes similarly to the shipping company. This can be explained because the shipping company plays a dominant role in the port of Tanger-Med by owning the terminals.

E.5 individual results

E.6 Results from RAK Ports

E.6.1. Results from Harbour Master

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.528	OPEX	0.125	0.066
		CAPEX	0.313	0.165
		Added value to port call	0.500	0.264
		Number of port calls	0.063	0.033
Operational Criteria	0.111	Delays	0.084	0.009
		On time processes	0.084	0.009
		Turn-around time	0.098	0.011
		Environmental affect	0.157	0.017
		Asset Utilisation	0.157	0.017
		Flexibility	0.030	0.003
		(Data) Availability	0.167	0.019
		(Data) Reliability	0.167	0.019
		User-friendliness	0.056	0.006
Safety Criteria	0.361	Incidents	0.250	0.090
		Near miss reports	0.250	0.090
		(Cyber) Security	0.250	0.090
		Robustness	0.250	0.090

Table E.7: Weights of Harbour Master RAK Ports

E.6.2. Results from Port Manager

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.455	OPEX	0.106	0.048
		CAPEX	0.106	0.048
		Added value to port call	0.719	0.327
		Number of port calls	0.069	0.031
Operational Criteria	0.455	Delays	0.182	0.083
		On time processes	0.249	0.113
		Turn-around time	0.182	0.083
		Environmental affect	0.083	0.038
		Asset Utilisation	0.083	0.038
		Flexibility	0.083	0.038
		(Data) Availability	0.039	0.018
		(Data) Reliability	0.050	0.023
		User-friendliness	0.050	0.023
Safety Criteria	0.091	Incidents	0.477	0.043
		Near miss reports	0.205	0.019
		(Cyber) Security	0.205	0.019
		Robustness	0.114	0.010

Table E.8: Weights of Port Manager RAK Ports

E.7 Results from Antwerp-Bruges

E.7.1. Terminal

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.069	OPEX	0.106	0.007
		CAPEX	0.106	0.007
		Added value to port call	0.638	0.044
		Number of port calls	0.149	0.010
Operational Criteria	0.448	Delays	0.165	0.074
		On time processes	0.165	0.074
		Turn-around time	0.181	0.081
		Environmental affect	0.035	0.016
		Asset Utilisation	0.131	0.059
		Flexibility	0.165	0.074
		(Data) Availability	0.071	0.032
		(Data) Reliability	0.071	0.032
		User-friendliness	0.017	0.007
Safety Criteria	0.483	Incidents	0.350	0.169
		Near miss reports	0.450	0.217
		(Cyber) Security	0.150	0.072
		Robustness	0.050	0.024

Table E.9: Weights of Terminal Antwerp-Bruges

E.7.2. Tug Operator

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.167	OPEX	0.076	0.013
		CAPEX	0.214	0.036
		Added value to port call	0.550	0.092
		Number of port calls	0.160	0.027
Operational Criteria	0.292	Delays	0.122	0.036
		On time processes	0.082	0.024
		Turn-around time	0.041	0.012
		Environmental affect	0.184	0.054
		Asset Utilisation	0.224	0.065
		Flexibility	0.122	0.036
		(Data) Availability	0.082	0.024
		(Data) Reliability	0.122	0.036
		User-friendliness	0.020	0.006
Safety Criteria	0.542	Incidents	0.243	0.132
		Near miss reports	0.243	0.132
		(Cyber) Security	0.108	0.059
		Robustness	0.405	0.220

Table E.10: Weights of Tug operator

E.7.3. Port Authority

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.111	OPEX	0.144	0.016
		CAPEX	0.144	0.016
		Added value to port call	0.633	0.070
		Number of port calls	0.078	0.009
Operational Criteria	0.244	Delays	0.215	0.052
		On time processes	0.145	0.036
		Turn-around time	0.145	0.036
		Environmental affect	0.073	0.018
		Asset Utilisation	0.035	0.008
		Flexibility	0.097	0.024
		(Data) Availability	0.097	0.024
		(Data) Reliability	0.097	0.024
		User-friendliness	0.097	0.024
Safety Criteria	0.644	Incidents	0.466	0.300
		Near miss reports	0.103	0.067
		(Cyber) Security	0.172	0.111
		Robustness	0.259	0.167

Table E.11: Weights of PA Antwerp

E.8 Results from Port Arthur

E.8.1. Tug Operator Commercial Manager

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.091	OPEX	0.152	0.014
		CAPEX	0.152	0.014
		Added value to port call	0.626	0.057
		Number of port calls	0.071	0.006
Operational Criteria	0.131	Delays	0.078	0.010
		On time processes	0.078	0.010
		Turn-around time	0.078	0.010
		Environmental affect	0.416	0.055
		Asset Utilisation	0.078	0.010
		Flexibility	0.078	0.010
		(Data) Availability	0.078	0.010
		(Data) Reliability	0.078	0.010
		User-friendliness	0.041	0.005
Safety Criteria	0.778	Incidents	0.587	0.456
		Near miss reports	0.067	0.052
		(Cyber) Security	0.192	0.150
		Robustness	0.154	0.120

Table E.12: Weights of Commercial manager Tug operator

E.8.2. Tug Operator Operational manager

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.077	OPEX	0.192	0.015
		CAPEX	0.192	0.015
		Added value to port call	0.115	0.009
		Number of port calls	0.500	0.038
Operational Criteria	0.205	Delays	0.126	0.026
		On time processes	0.272	0.056
		Turn-around time	0.063	0.013
		Environmental affect	0.024	0.005
		Asset Utilisation	0.126	0.026
		Flexibility	0.126	0.026
		(Data) Availability	0.075	0.015
		(Data) Reliability	0.094	0.019
		User-friendliness	0.094	0.019
Safety Criteria	0.718	Incidents	0.304	0.218
		Near miss reports	0.203	0.145
		(Cyber) Security	0.063	0.045
		Robustness	0.430	0.309

Table E.13: Weights of Operational manager Tug operator

E.8.3. Pilots

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.083	OPEX	0.111	0.009
		CAPEX	0.059	0.005
		Added value to port call	0.148	0.012
		Number of port calls	0.681	0.057
Operational Criteria	0.646	Delays	0.181	0.117
		On time processes	0.078	0.050
		Turn-around time	0.078	0.050
		Environmental affect	0.018	0.012
		Asset Utilisation	0.218	0.141
		Flexibility	0.078	0.050
		(Data) Availability	0.116	0.075
		(Data) Reliability	0.116	0.075
		User-friendliness	0.116	0.075
Safety Criteria	0.271	Incidents	0.331	0.090
		Near miss reports	0.038	0.010
		(Cyber) Security	0.158	0.043
		Robustness	0.474	0.128

Table E.14: Weights of Pilots

E.9 Results from Sydney

E.9.1. Tug Operator

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.756	OPEX	0.210	0.158
		CAPEX	0.066	0.050
		Added value to port call	0.585	0.442
		Number of port calls	0.140	0.106
Operational Criteria	0.144	Delays	0.072	0.010
		On time processes	0.087	0.013
		Turn-around time	0.108	0.016
		Environmental affect	0.072	0.010
		Asset Utilisation	0.144	0.021
		Flexibility	0.087	0.013
		(Data) Availability	0.025	0.004
		(Data) Reliability	0.087	0.013
		User-friendliness	0.318	0.046
Safety Criteria	0.100	Incidents	0.268	0.027
		Near miss reports	0.134	0.013
		(Cyber) Security	0.056	0.006
		Robustness	0.542	0.054

Table E.15: Weights of Tug operator

E.9.2. Port Authority

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.077	OPEX	0.154	0.012
		CAPEX	0.077	0.006
		Added value to port call	0.577	0.044
		Number of port calls	0.192	0.015
Operational Criteria	0.187	Delays	0.183	0.034
		On time processes	0.284	0.053
		Turn-around time	0.122	0.023
		Environmental affect	0.122	0.023
		Asset Utilisation	0.073	0.014
		Flexibility	0.034	0.006
		(Data) Availability	0.061	0.011
		(Data) Reliability	0.061	0.011
		User-friendliness	0.061	0.011
Safety Criteria	0.736	Incidents	0.300	0.221
		Near miss reports	0.429	0.316
		(Cyber) Security	0.214	0.158
		Robustness	0.057	0.042

Table E.16: Weights of Port Authority

E.10 Results from Tanger-Med

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.100	OPEX	0.064	0.006
		CAPEX	0.119	0.012
		Added value to port call	0.521	0.052
		Number of port calls	0.297	0.030
Operational Criteria	0.575	Delays	0.151	0.087
		On time processes	0.269	0.154
		Turn-around time	0.034	0.019
		Environmental affect	0.101	0.058
		Asset Utilisation	0.076	0.043
		Flexibility	0.076	0.043
		(Data) Availability	0.151	0.087
		(Data) Reliability	0.101	0.058
		User-friendliness	0.043	0.025
Safety Criteria	0.325	Incidents	0.466	0.151
		Near miss reports	0.259	0.084
		(Cyber) Security	0.172	0.056
		Robustness	0.103	0.034

Table E.17: Weights of Port Authority Tanger-Med

E.11 Shipping Company

Main criteria	Local weights	Sub-criteria	Local weights	Global weights
Commercial Criteria	0.067	OPEX	0.213	0.014
		CAPEX	0.213	0.014
		Added value to port call	0.517	0.034
		Number of port calls	0.056	0.004
Operational Criteria	0.583	Delays	0.039	0.023
		On time processes	0.208	0.122
		Turn-around time	0.138	0.080
		Environmental affect	0.138	0.080
		Asset Utilisation	0.138	0.080
		Flexibility	0.018	0.010
		(Data) Availability	0.092	0.054
		(Data) Reliability	0.138	0.080
		User-friendliness	0.092	0.054
Safety Criteria	0.350	Incidents	0.098	0.034
		Near miss reports	0.517	0.181
		(Cyber) Security	0.044	0.015
		Robustness	0.341	0.120

Table E.18: Weights of Shipping Company

F

Credal Ranking

F.1 Credal Ranking Antwerp-Bruges

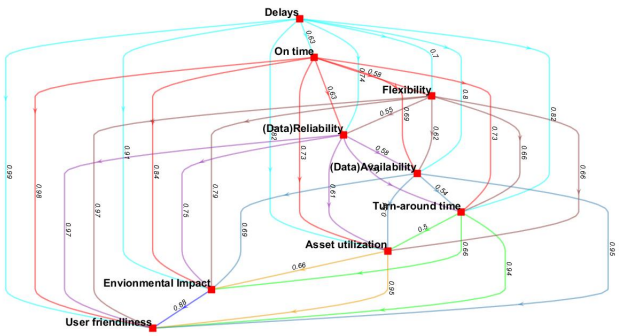


Figure F.1: Credal Ranking Antwerp sub criteria Operational criteria

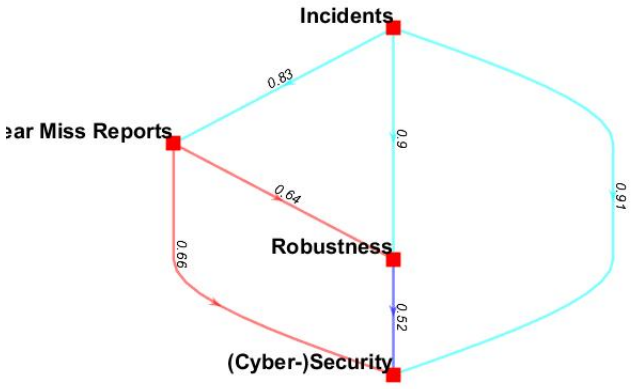


Figure F.2: Credal Ranking Antwerp sub criteria Safety criteria

F.2 Credal Ranking Port Arthur

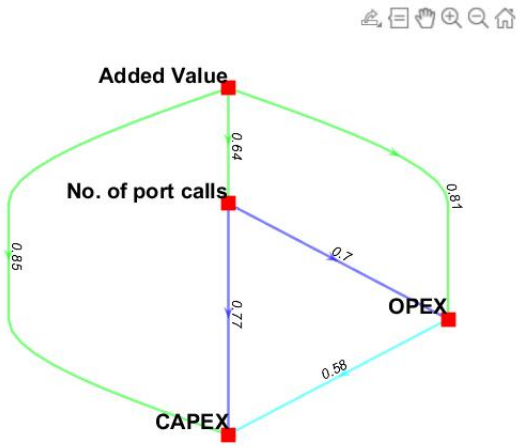


Figure F.3: Credal Ranking Port Arthur sub criteria commercial criteria

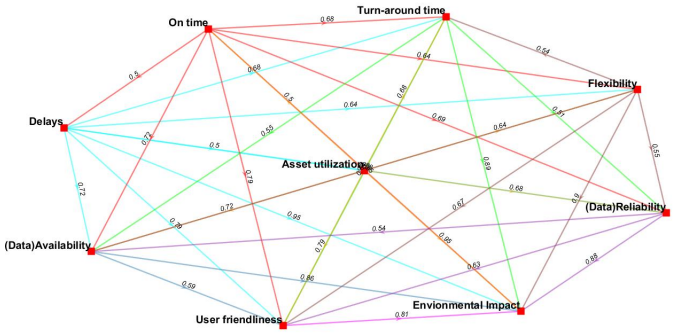


Figure F.4: Credal Ranking Port Arthur sub criteria operational criteria

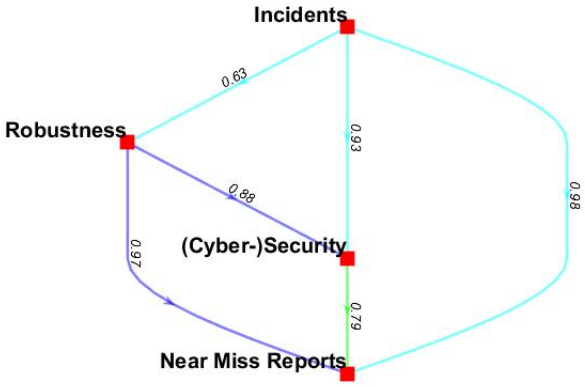


Figure F.5: Credal Ranking Port Arthur sub criteria safety criteria